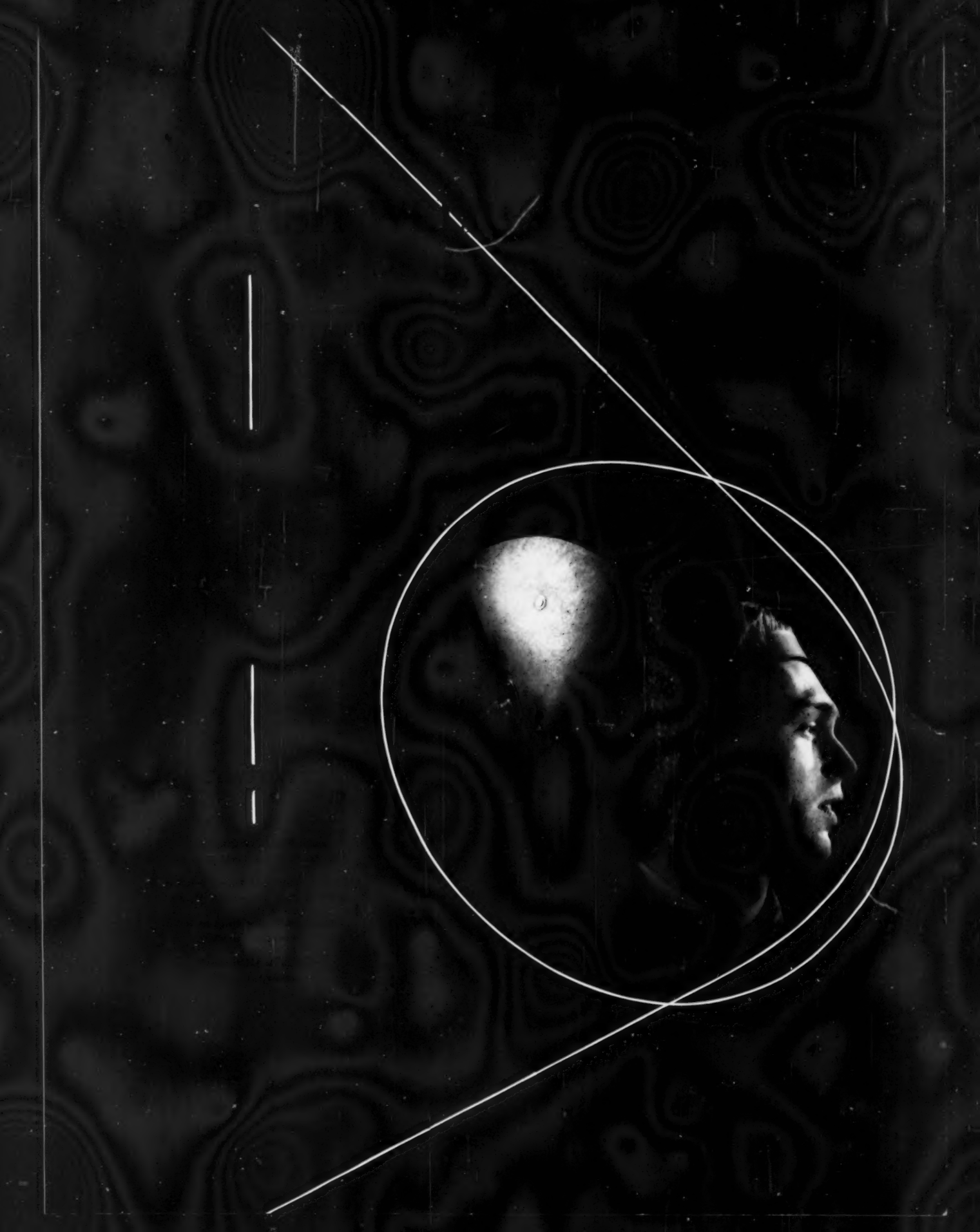
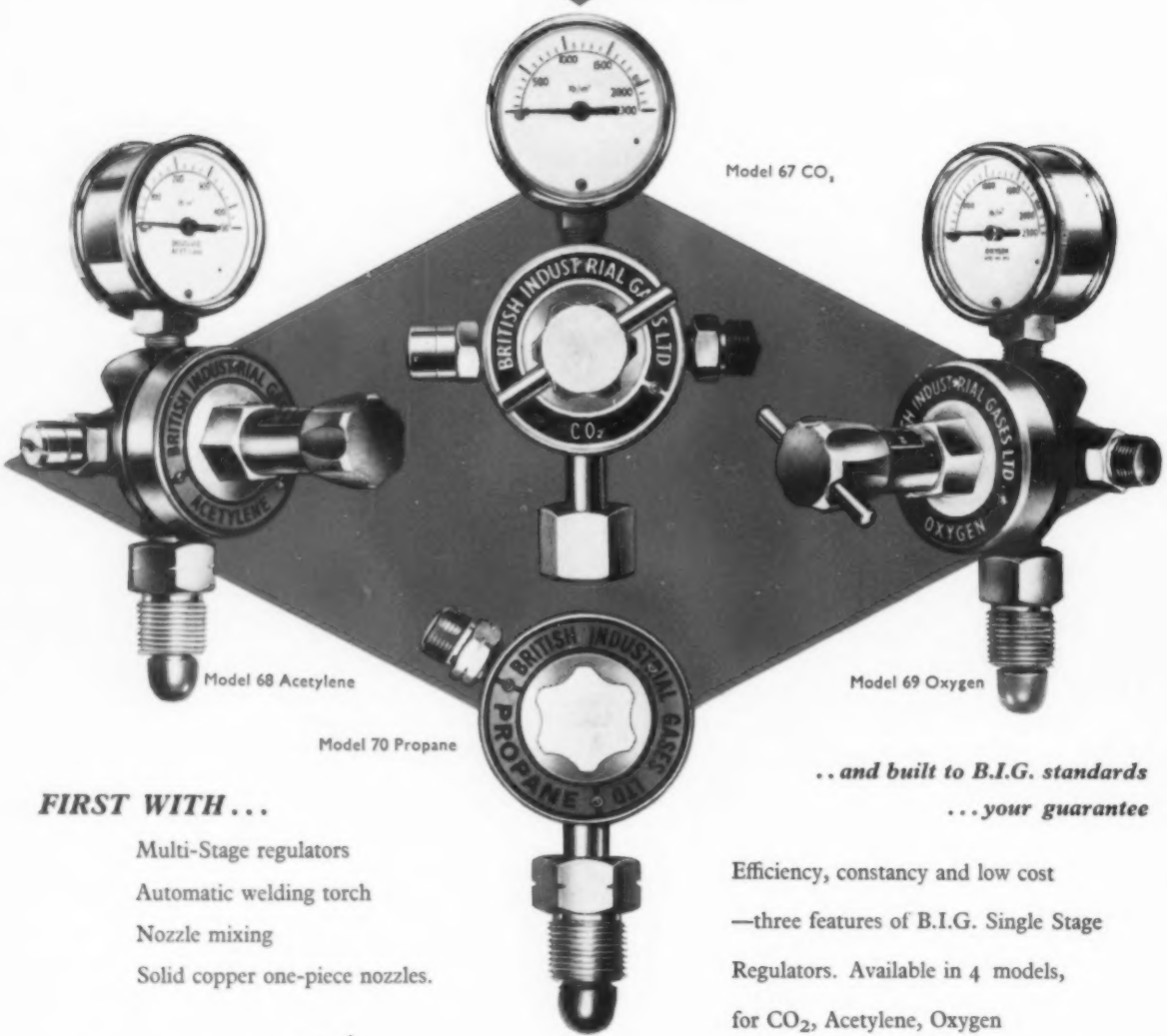


still in the lead–

maintaining

B.I.G. *excellence*



Model 67 CO_2

Model 68 Acetylene

Model 69 Oxygen

Model 70 Propane

FIRST WITH...

Multi-Stage regulators

Automatic welding torch

Nozzle mixing

Solid copper one-piece nozzles.

...and built to B.I.G. standards

...your guarantee

Efficiency, constancy and low cost —three features of B.I.G. Single Stage Regulators. Available in 4 models, for CO_2, Acetylene, Oxygen and Propane, trouble-free units built for long life service under tough conditions.

Hand finished –individually tested

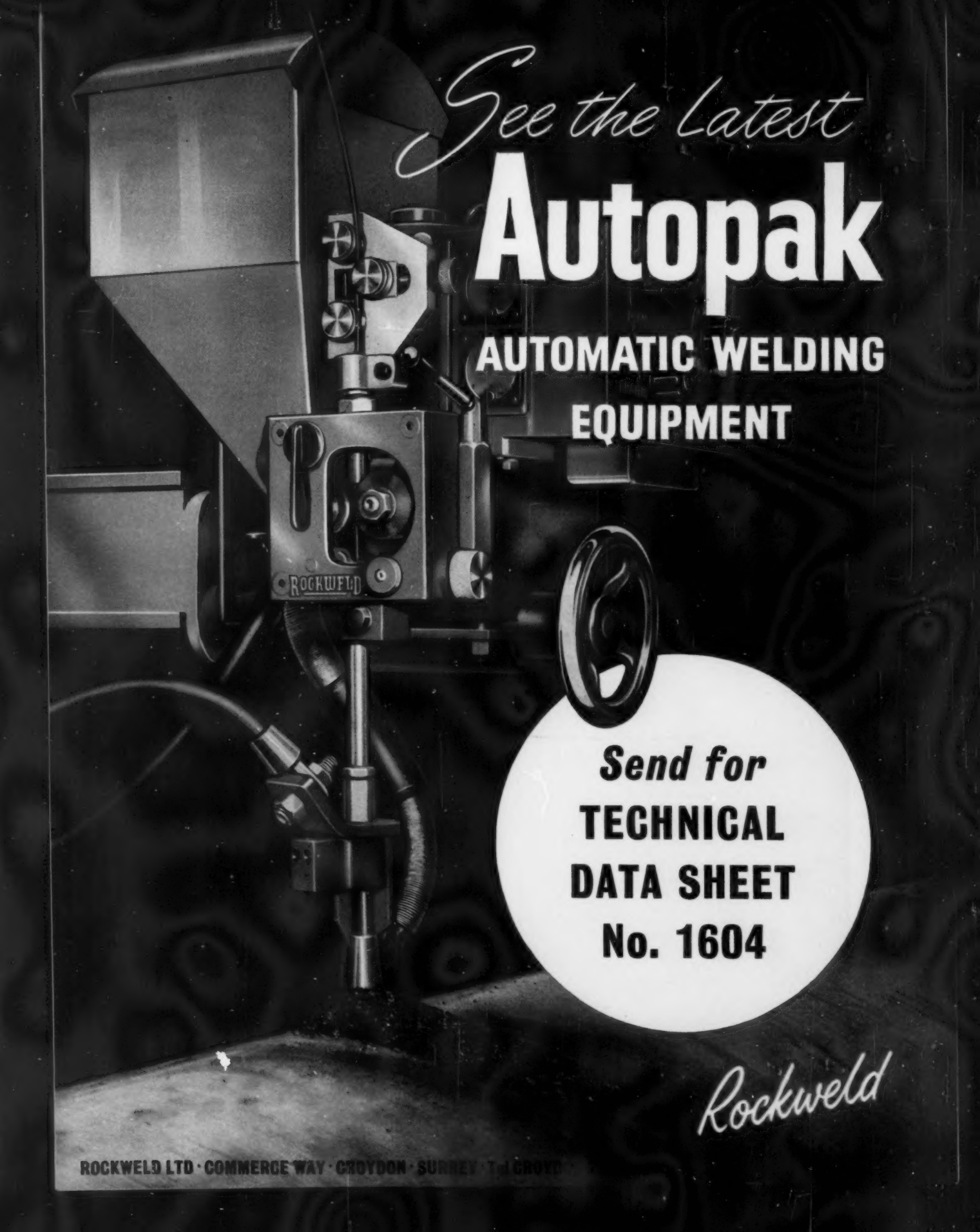
British Industrial Gases Limited

700, GT. CAMBRIDGE RD, ENFIELD, MIDDX. Telephone: **ENField 4022,** Telex: **24128**

Sales and Technical Assistance available in most areas

NRP 2187

Inside front cover



See the Latest

Autopak

AUTOMATIC WELDING EQUIPMENT

Send for
TECHNICAL DATA SHEET No. 1604

Rockweld

ROCKWELD LTD · COMMERCE WAY · CROYDON · SURREY · T

THE MALLORY FORMULA

$$D = \sqrt{t}$$

The formula $D = \sqrt{t}$ for the relationship between electrode tip diameter "D" and work thickness "t" was devised by MALLORY. Welding engineers the world over have adopted it as a reliable aid to efficient operation.

Material is as important as design – and here again MALLORY leadership shows itself, for the superior properties of Mallory 3 are universally recognised.

In design and in material . . . the first name is MALLORY

Booklet 1200 "Mallory Resistance Welding" is free on request.

Johnson Matthey
MALLORY

JOHNSON, MATTHEY & CO., LIMITED

Controlling MALLORY METALLURGICAL PRODUCTS LTD.,
73-83 HATTON GARDEN, LONDON, E.C.1.
Telephone: Holborn 6989
Vittoria Street, Birmingham, 1. Telephone: Central 8004
75–79 Eyre Street, Sheffield, 1. Telephone: 29212.

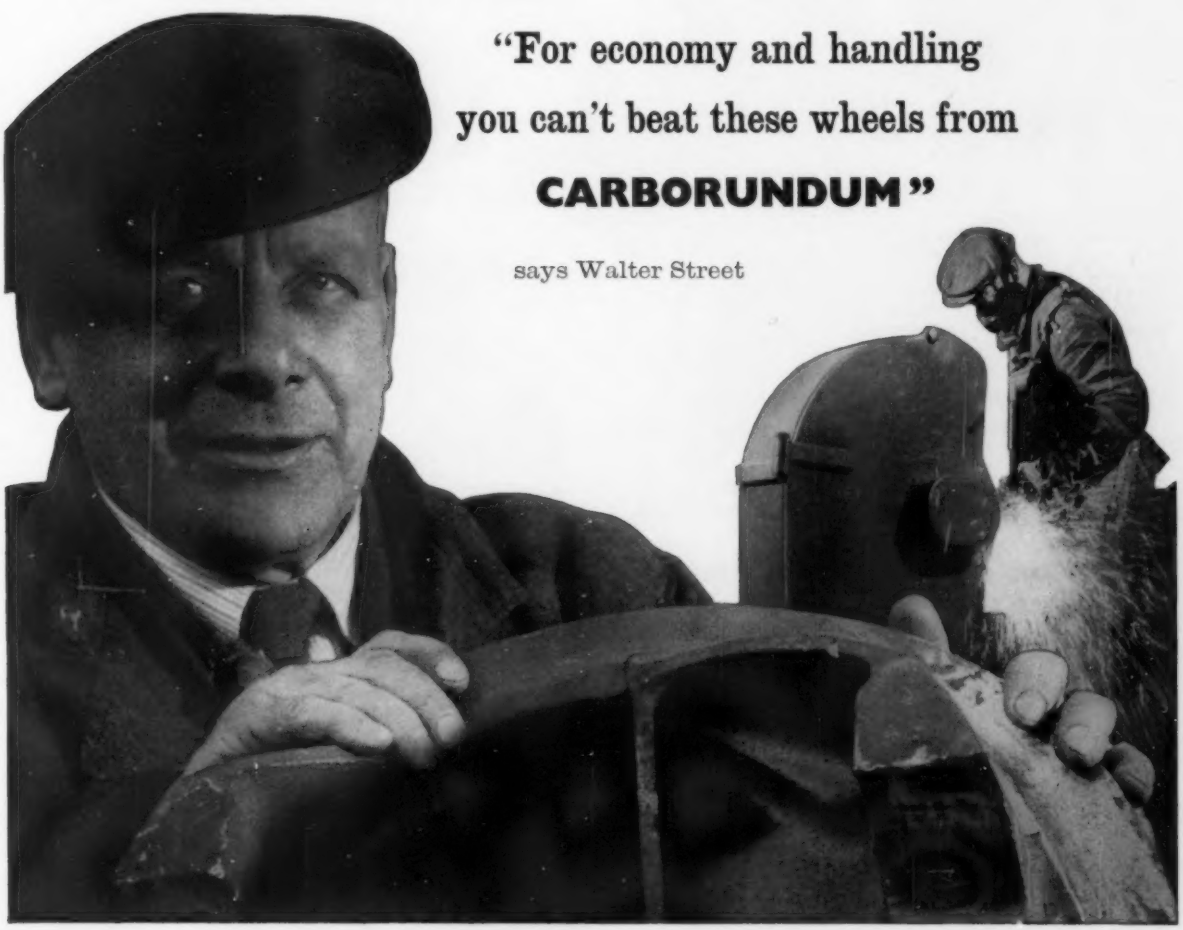
W.91

CUSTOMERS OF CARBORUNDUM

Leys Malleable Castings, in Derby, is one of the biggest foundries in the country, and they've been using CARBORUNDUM'S wheels since 1927. We spoke to foreman Wat Street, who has been there a good 36 years. Pointing to a batch of gear housings, Wat said: "We're proud to export such well-fettled products. These wheels from CARBORUNDUM stand up to heavy feeder removal and cut-out, yet they wear from 36" to 15½" without losing their sharp grinding corners. We're not exactly gentle on the wheels, but any of the men will tell you that you can't beat them for durability and easy handling."

"For economy and handling you can't beat these wheels from CARBORUNDUM"

says Walter Street



CARBORUNDUM can help YOU

In most of the major industries of the world, CARBORUNDUM is helping top firms to make better products, to cut costs, and to speed production. In the sharply competitive industrial climate of today there are three main conditions for success: high quality, low prices, and early deliveries. CARBORUNDUM can help you to meet them all.

Products by

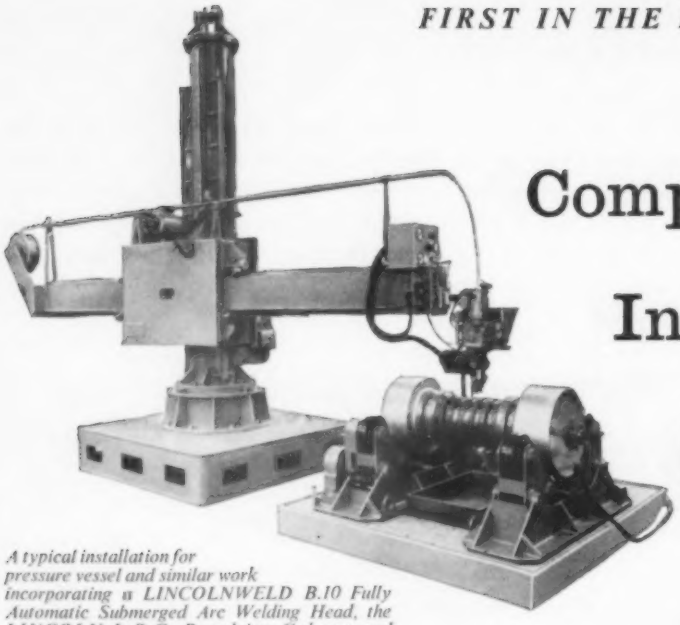
CARBORUNDUM

TRADE MARK

can cut your costs

THE CARBORUNDUM COMPANY LIMITED · TRAFFORD PARK · MANCHESTER 17 · PHONE TRAFFORD PARK 2381

Complete Welding Installations by LINCOLN



A typical installation for pressure vessel and similar work incorporating a LINCOLNWELD B.10 Fully Automatic Submerged Arc Welding Head, the LINCOLN L.R.C. Revolving Column and Travelling Boom and LINCOLN L.S.A.R. Self-Aligning Variable Speed Rotators.

★ **AUTOMATIC AND SEMI-AUTOMATIC SUBMERGED ARC WELDING UNITS**

★ **POSITIONING AND MANIPULATIVE EQUIPMENT**

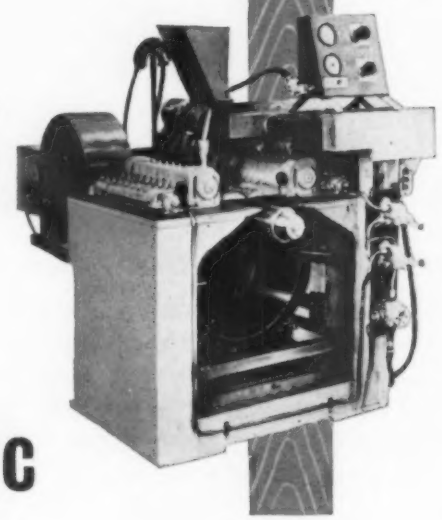
★ **WIRES AND FLUXES FOR MILD STEEL, ALLOY STEELS AND HARDFACING**

★ **AFTER-SALES SERVICE**

The LINCOLN 150 L.V.P. Variable Speed Positioner (load capacity 7½ tons)

Sooner or later YOU will become interested in Submerged Arc Welding.
LINCOLN have a COMPLETE range of Submerged Arc Welding Equipment PLUS
★ Hundreds of successful installations.
★ Years of knowledge acquired throughout the world.
★ A fully trained staff of Design and Welding Engineers.
Let LINCOLN be YOUR Welding Consultant.

Please write to:



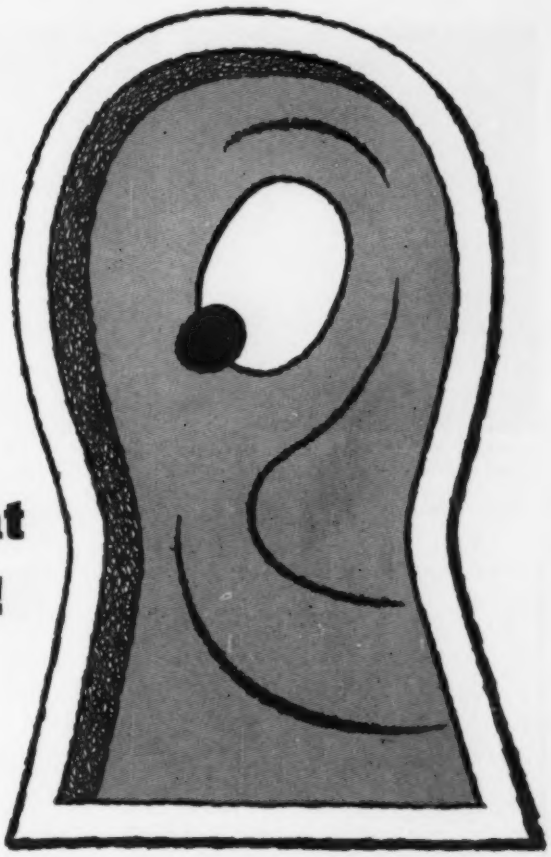
A LINCOLN Seam Welding Machine, incorporating the LINCOLNWELD M.L.3. Remote Control Automatic Submerged Arc Welding Unit.

The Automatic Division

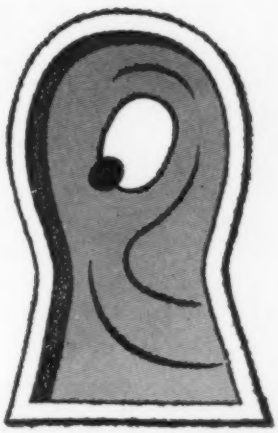
LINCOLN ELECTRIC COMPANY LIMITED

WELWYN GARDEN CITY · HERTS · WELWYN GARDEN 920 (5 lines) 4581 (5 lines)

P.7.



You'd be surprised what MAPEL can see!



. . . especially if you're worried about the efficiency of your welding.

MAPEL — acknowledged leaders in the field of Welding Inspection — have seen stub ends of electrodes, rusty pieces of bar, parts of rivets and even a full-sized chisel in faulty welds! Not that *all* welding faults are deliberate. Many are due to lack of knowledge and bad techniques. MAPEL have the complete answer — can supply skilled advice on the correct techniques, procedure and practice . . . can train your welders to high standards . . . can test welds speedily by visual, radiographic and the latest ultrasonic means.

Call in MAPEL for Welding Inspection — for corrosion surveys and leak detection, too.

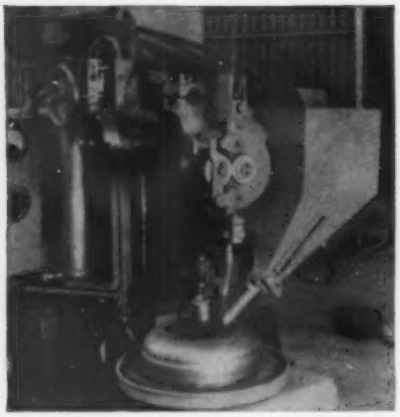
Get the facts from

MAPEL

METAL & PIPELINE ENDURANCE LTD.,
Artillery Mansions, Victoria Street, London, S.W.1.
Tel: ABBey 6056 'Grams: Metaldure, Sowest, London

Divisional offices at Woolmer Green, Herts; also at Newcastle-on-Tyne and Glasgow.
AGENTS THROUGHOUT THE WORLD

1. After the hub of the impeller has been pressed into its shell, the hub plate is welded inside the shell using a Metrovick 600 kVA projection welder.

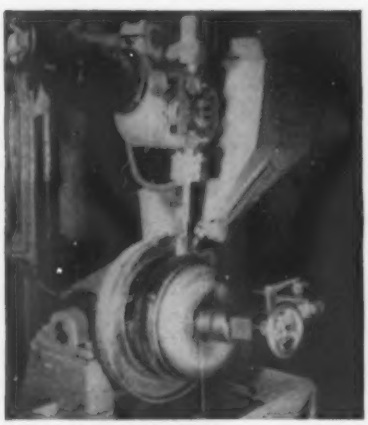


2. For welding the hub to the impeller shell a Metrovick submerged arc unit is used. An essential feature of this machine is the electronic control of the arc.

3. After vanes have been inserted, a filler adapter drain plug is welded into the impeller shell. A counterbalance weight is welded on the diametrically opposite side. This is carried out on a Metrovick 150 kVA air-operated projection welder, automatically setting the weld time for each operation.

Fabricating the BORG-WARNER HYDRAULIC TORQUE CONVERTER

4. The turbine assembly must be balanced to within 0.1 oz.-in. Balance is corrected by spot welding strip metal on to the vanes using a Metrovick 50 kVA portable machine.



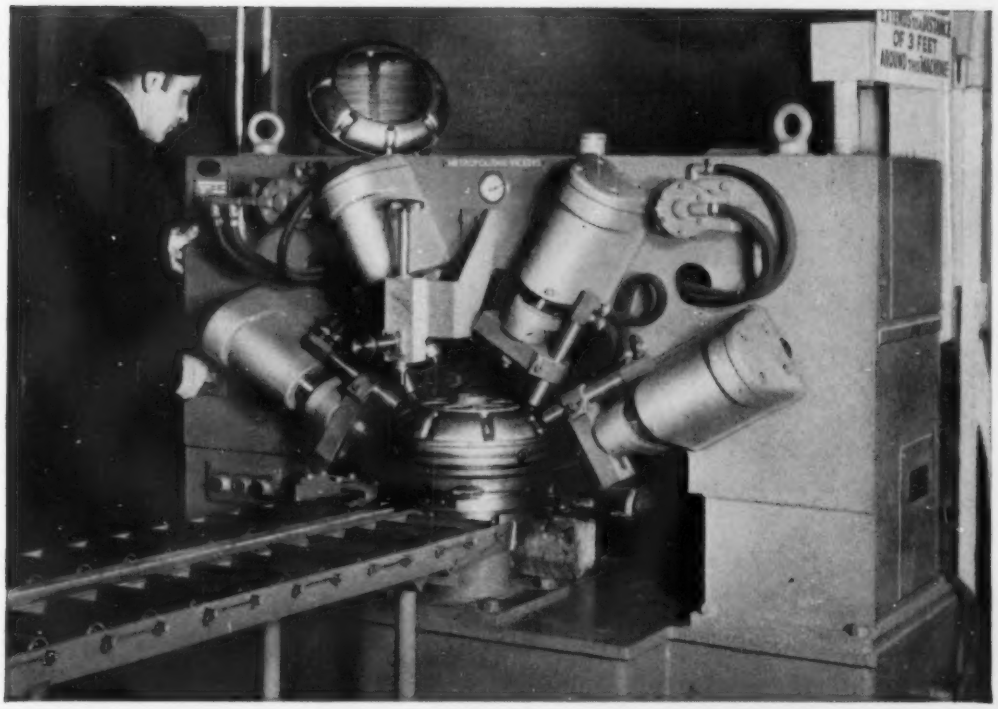
5. The completed clutch and flywheel assembly and the converter assembly are fitted together and then welded with a Metrovick submerged arc machine. This was specially designed for circumferential welds on Borg-Warner converter casings.

6. After testing the assembly for leaks a Metrovick Archway Type multi-spot unit is used to attach the blower. Sixteen spot welds are made with four air-operated heads. Control is by thyratron timer and ignitron contactor.

7. In the final balancing of the complete assembly this Metrovick 75 kVA portable spot welder is used for welding weights to the outer casing. The air-operated welding gun is mounted on a pivoting arm, balanced for ease of manipulation.

L/W803

Metrovick Welding Equipment for Modern Engineering

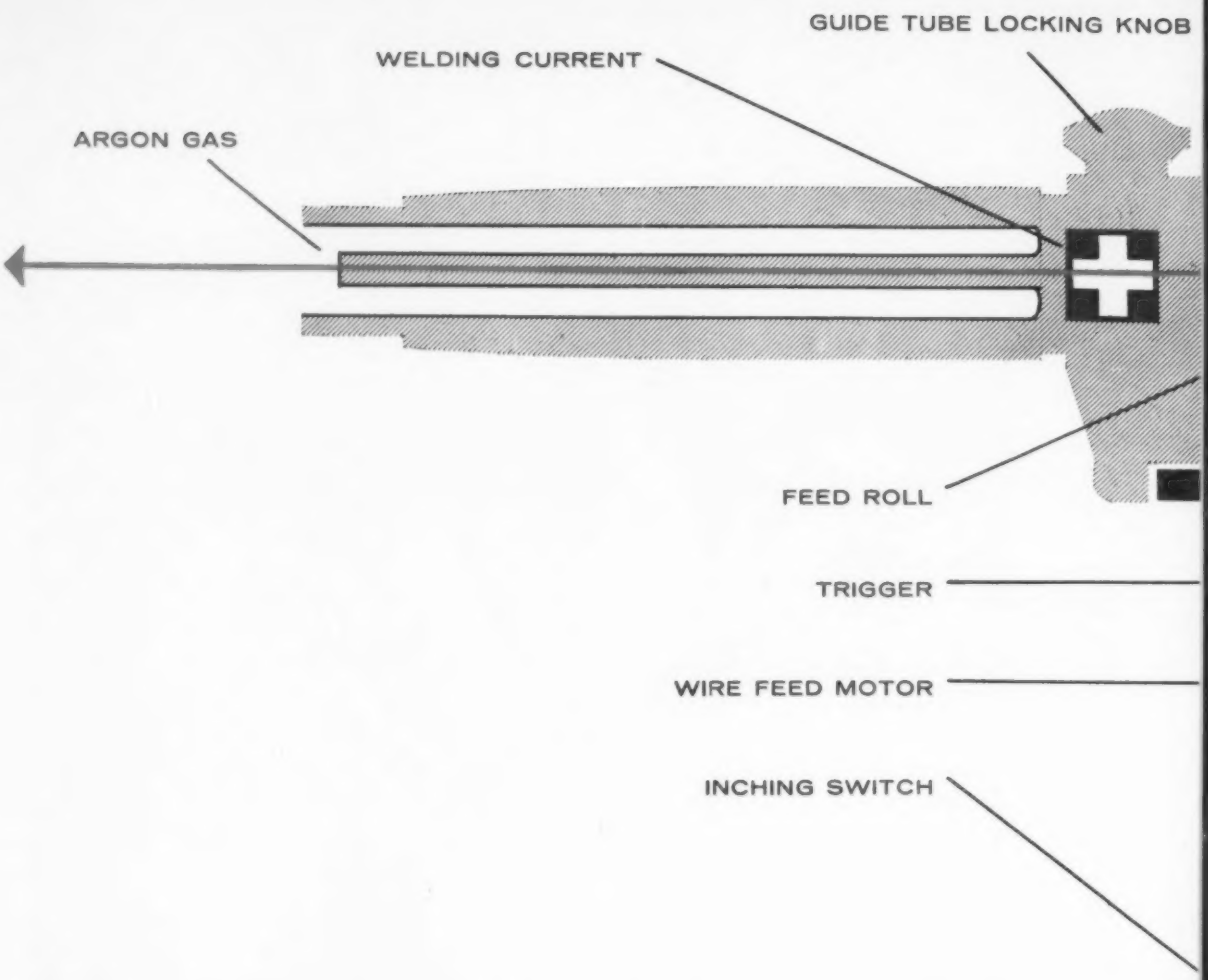


Borg-Warner automatic transmission used on British and Continental cars is now produced entirely in this country. The fabrication of the hydraulic torque converter is an achievement which depended largely on solving a number of welding problems. Distortion had to be avoided because of the close dimensional tolerances required in many components and only a small departure from true balance is permissible with the high rotary speeds employed in the converters. In addition, the economics of present-day production necessitated fast, automatic welding techniques. All of these exacting and important welding requirements have been met by the use of several different types of Metrovick automatic submerged arc and resistance welding equipments, including a number of machines specially designed for the job.

Associated Electrical Industries Limited

TRANSFORMER DIVISION — HEATING & WELDING DEPARTMENT

Trafford Park - - - Manchester 17

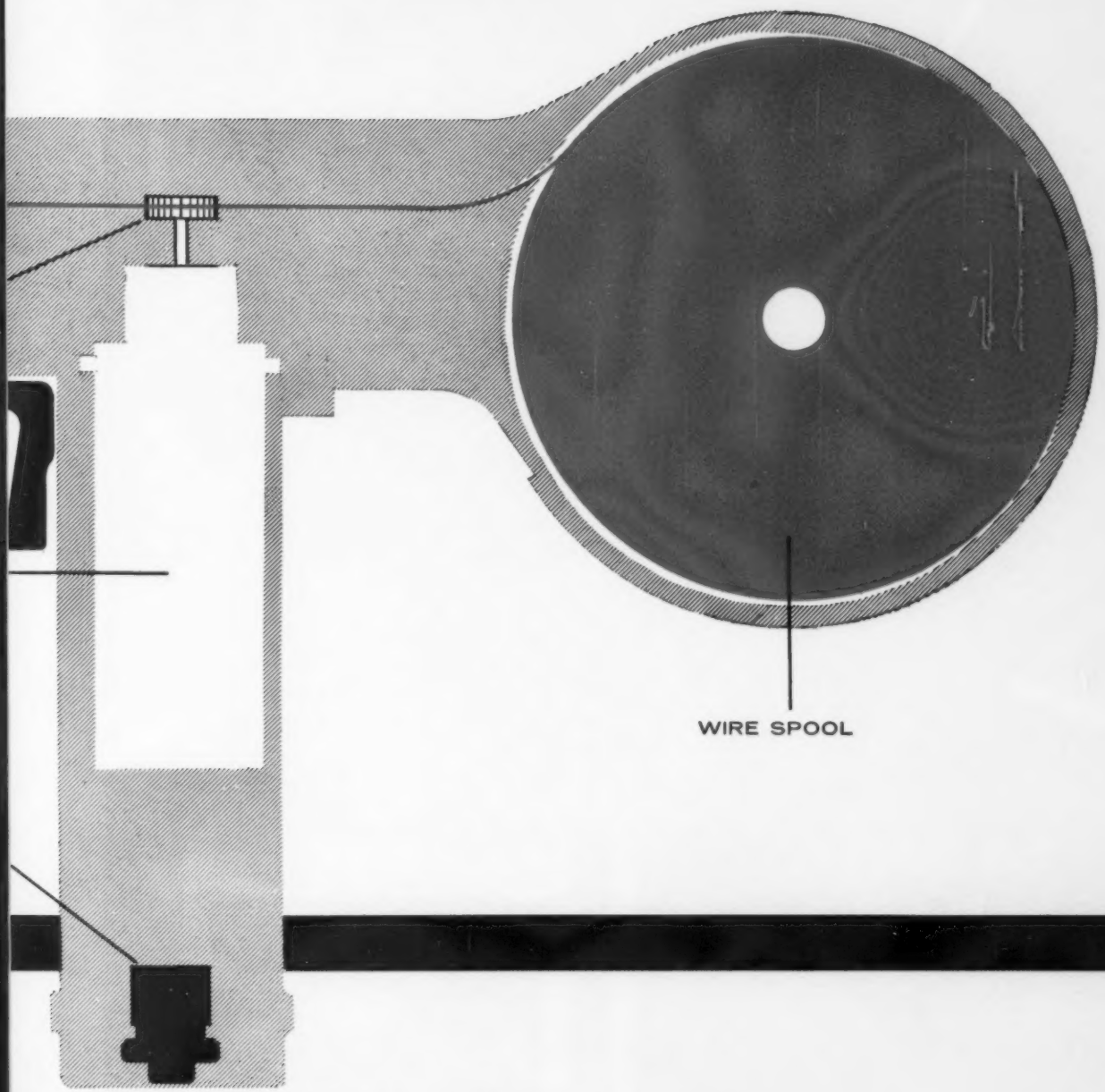


Quasi-Arc introduce SIGMETTE for new ease and

SIGMETTE — Quasi-Arc's new thin-wire portable equipment brings new ease and speed of operation to welding thin-gauge aluminium and mild steel. Count its features, and you'll see how:—

- Gun is light (3 lb. 1 oz.) and well balanced for easy handling and simplicity of all-position welding.
- One standard gun covers whole range of wire sizes. (Medium speed drive motor can be changed readily for high or low speed versions to extend application range.)
- Maximum portability — gun is self-contained unit with wire spool, feed motor and trigger control.
- Uses wire from 0.030″ to 1/16″ in diameter.
- Once wire-feed speed has been set on control unit (supplied as standard fitting with 30 ft. leads to gun) all functions —

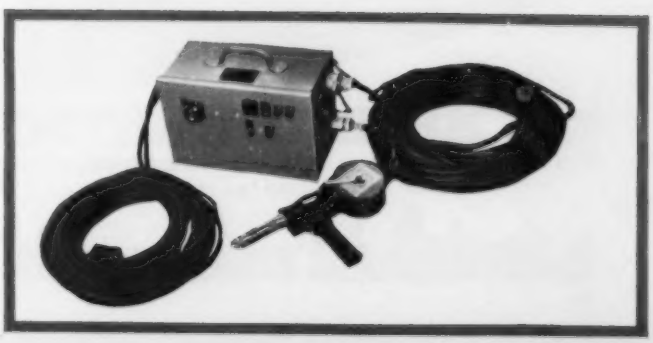
Quasi-Arc



speed in thin wire welding

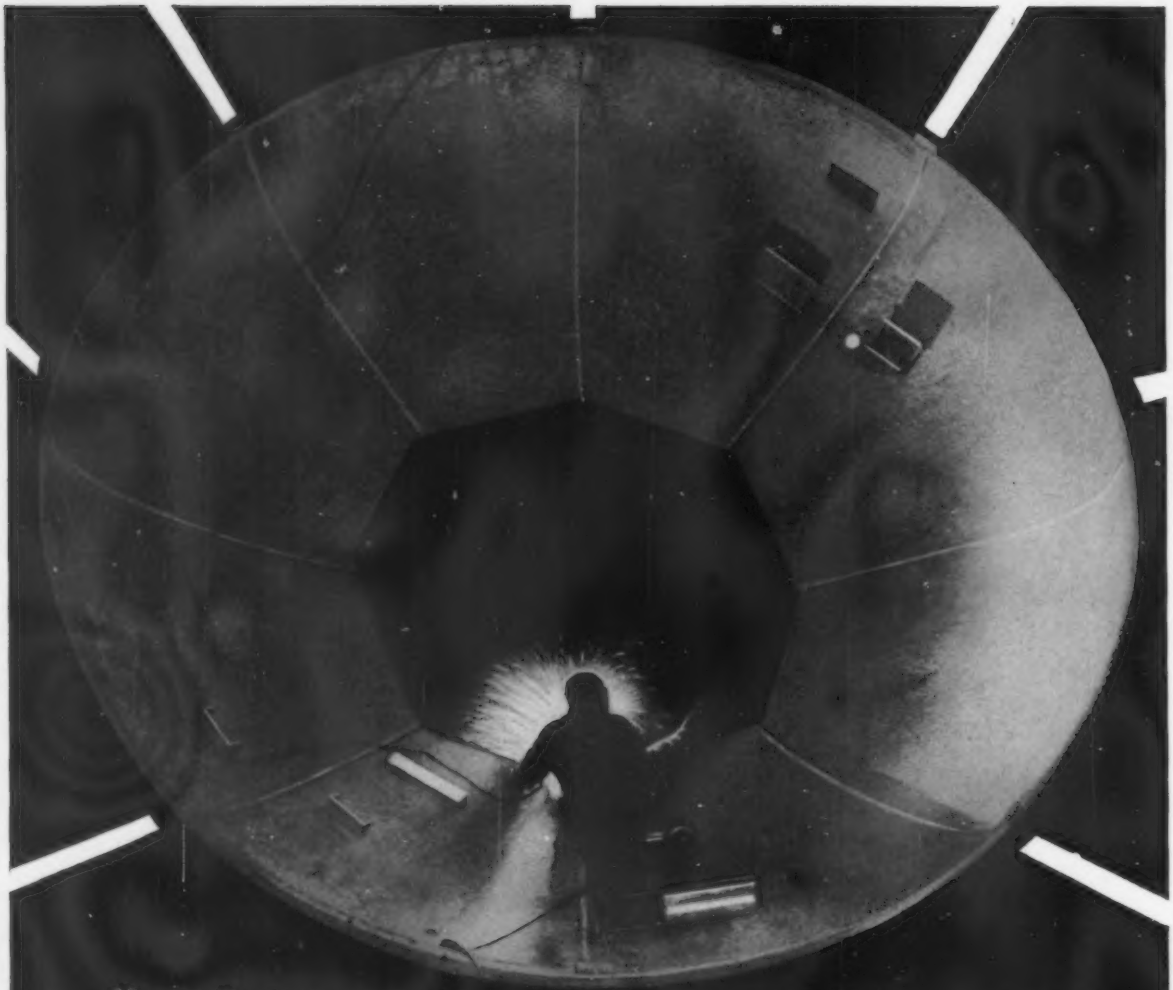
wire feed, argon flow, etc. — are operated by trigger on gun.
- Inching button for optimum arc striking characteristics.
- Easy maintenance — only tool needed is screwdriver.

For full technical information on SIGMETTE, write to Quasi-Arc Limited, Bilston, Staffs.



world leaders in arc welding

Quasi-Arc Limited, Bilston, Staffordshire



Heat Exchangers for Bradwell

These large fabrications are the dished and flanged ends of the 19/20 feet diameter by 93 feet long heat exchangers for the Bradwell Nuclear Power Station. They consist of 8 segments $1\frac{9}{16}$" thick, joined by double sided manual welding. This is a typical example of the class of work that passes through the shops of Head Wrightson Teesdale Ltd. Equipment manufactured by the Company is used in docks, harbours, mines, refineries, steelworks etc., all over the world.

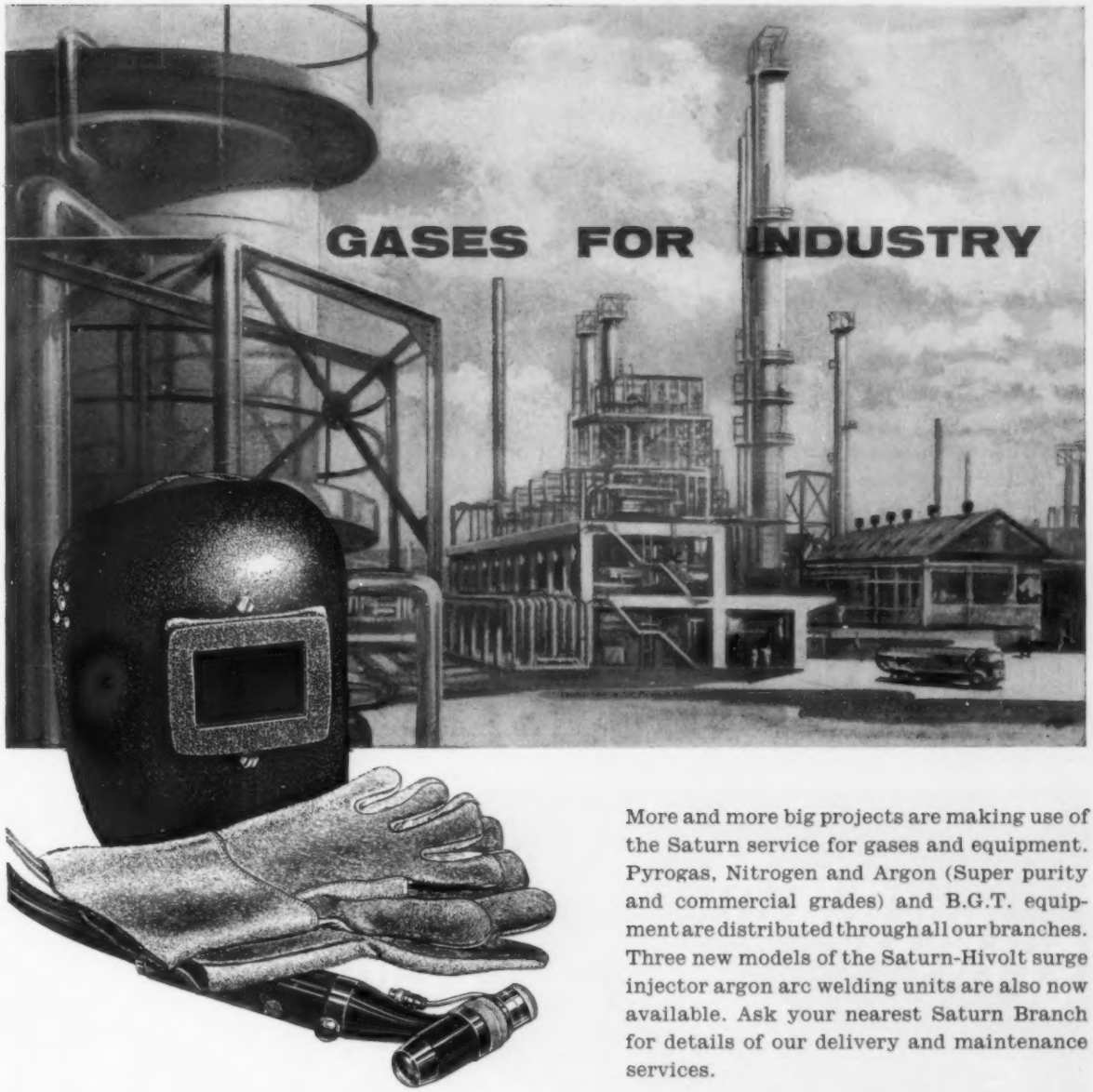
Inner side of the 8 segments making up the 20 feet diameter dished and flanged end.

Completing a seam on the outer side of the dished and flanged end.

HEAD WRIGHTSON TEESDALE LTD

TEESDALE IRON WORKS · THORNABY-ON-TEES

LONDON JOHANNESBURG TORONTO SYDNEY CALCUTTA



More and more big projects are making use of the Saturn service for gases and equipment. Pyrogas, Nitrogen and Argon (Super purity and commercial grades) and B.G.T. equipment are distributed through all our branches. Three new models of the Saturn-Hivolt surge injector argon arc welding units are also now available. Ask your nearest Saturn Branch for details of our delivery and maintenance services.

Contractors to: ADMIRALTY, MINISTRY OF SUPPLY, U.K. ATOMIC ENERGY AUTHORITY, AUSTRALIAN ATOMIC ENERGY AUTHORITY, NATIONAL COAL BOARD AND BRITISH RAILWAYS, BRISTOL SIDDELEY ENGINES LTD., FERRANTI LTD., HAWKER SIDDELEY NUCLEAR POWER CO. LTD., HEAD WRIGHTSON (TEESDALE) LTD., THE PLESSEY CO. LTD., ROOTES GROUP.

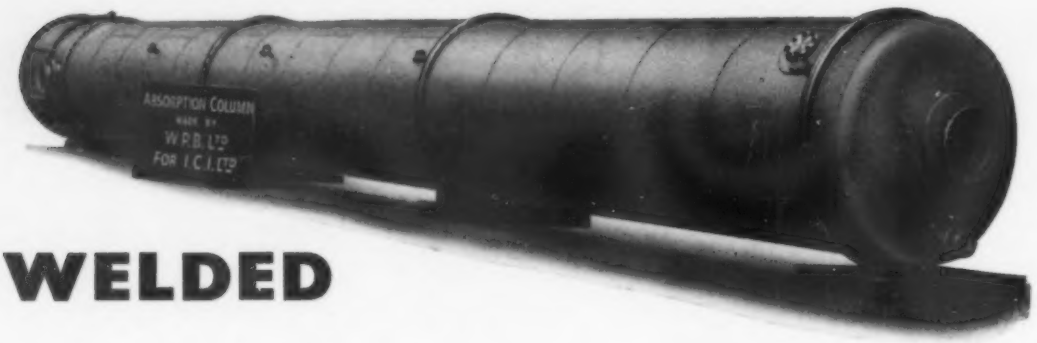
SATURN INDUSTRIAL GASES LTD

Gordon Rd., Southall, Middlesex. Tel: Southall 5611.

Branches: GLASGOW, ALDRIDGE, MANCHESTER, SHEFFIELD, LYMINGTON, SUNDERLAND, THORNABY-ON-TEES

SIG.1A

65 ft. overall length



WELDED STAINLESS STEEL PLANT

Butterfield craftsmen carry out welding with the most up-to-date equipment and at all stages of fabrication it is supervised by experts to any of the recognised codes

produced by

Butterfields of SHIPLEY

WELD X-RAY We are equipped with Weld X-Ray Plant, materials testing metallurgical, chemical and micro-scopic examination, laboratories for any required class of work

W. P. BUTTERFIELD Ltd P.O. BOX 38 Shipley Yorks. *Tel 52244 (8 lines)*
Branches London: Tel: HOLborn 2455 (4 lines) Birmingham Tel: EAS 0871 and EAS 2241
Bristol Tel: 27905 L'pool Tel: CENtral 0829 Glasgow Tel: CENtral 7696 Dublin Tel: 73475

SPENCER WIRE · SPENCER WIRE · SPENCER WIRE

Specify

"HUMBER" or "OUSE"

quality

Recognised for many years as first-class wires for electric arc welding electrodes

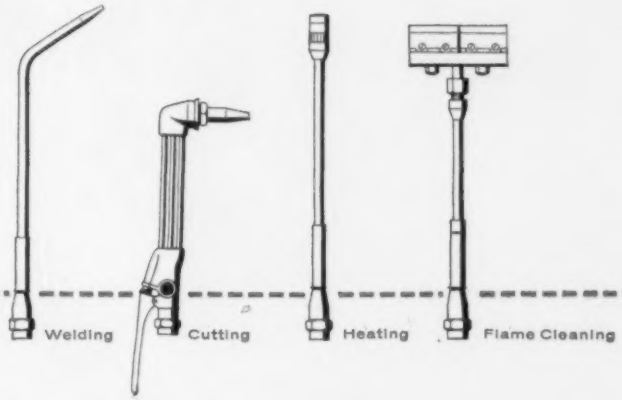
SPENCER WIRE · SPENCER WIRE · SPENCER WIRE · SPENCER WIRE · SPENCER ·

Write or telephone for further information

THE
SPENCER WIRE
COMPANY LIMITED • WAKEFIELD
Telephone • **WAKEFIELD 6111** *(10 lines)* • *Telegrams* • **SPENCER, WAKEFIELD, TELEX**
Telex No. **55,160**

DsW 959BW

FROM BRITISH OXYGEN — FOR BRITISH INDUSTRY



Sensational Saffire 4 blowpipes in 1

Common Shank to which any of these blowpipes can be fitted.

Recently introduced, the Saffire Combined Outfit has achieved outstanding success and widespread use in industry.

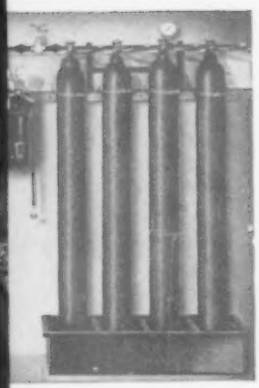
The Saffire, virtually 4 blowpipes in 1, is extremely efficient and economical in use. Here is a precision tool that has helped boost production for many thousands of users.

Buy the whole Saffire Outfit or just the common shank with the heads you need. Just consider how the Saffire Combined Outfit can increase *your own* production range and efficiency!

BOC **BRITISH OXYGEN**

British Oxygen Gases Ltd., Industrial Division,
Spencer House, 27 St. James's Place, London, S.W.1.

Photograph illustrating the FUSARC/CO_2 process by courtesy of Quasi-Arc Limited



The use of low pressure CO_2 gas as an inert shield in the welding of steels is increasing. CO_2 is not only cheap — it enables high quality welds to be made in the shortest time.

Where automatic welding machines have been specially modified to use this technique, the simplicity, ease of slag removal and high speed of welding have been found most impressive. On one differential housing, for example, welding time has been reduced from 105 to 23 seconds.

CO_2 ARC WELDING

DCL

The Carbon Dioxide Department of the D.C.L., with 30 years' experience of supplying CO_2 to industry, installs and maintains all necessary storage and gas supply equipment for CO_2 arc welding.

Single 28 lb. cylinders are supplied for experimental purposes. For continuous operation multi-cylinder racks are available discharging into a manifold. A typical transportable rack gives a continuous supply of gas at each of 4 points with individually controlled flows up to 6 lbs/hr. CO_2 is also available in solid form for use with 'Cardice' Converters.

Bulk liquid can be pumped direct from the Company's road tankers into customers' static tanks (of capacity $1\frac{1}{2}$ or 6 tons) without interrupting the flow of CO_2 to the operators.

All enquiries for further information should be addressed to:

THE DISTILLERS COMPANY LIMITED

Chemical Division—Carbon Dioxide Department

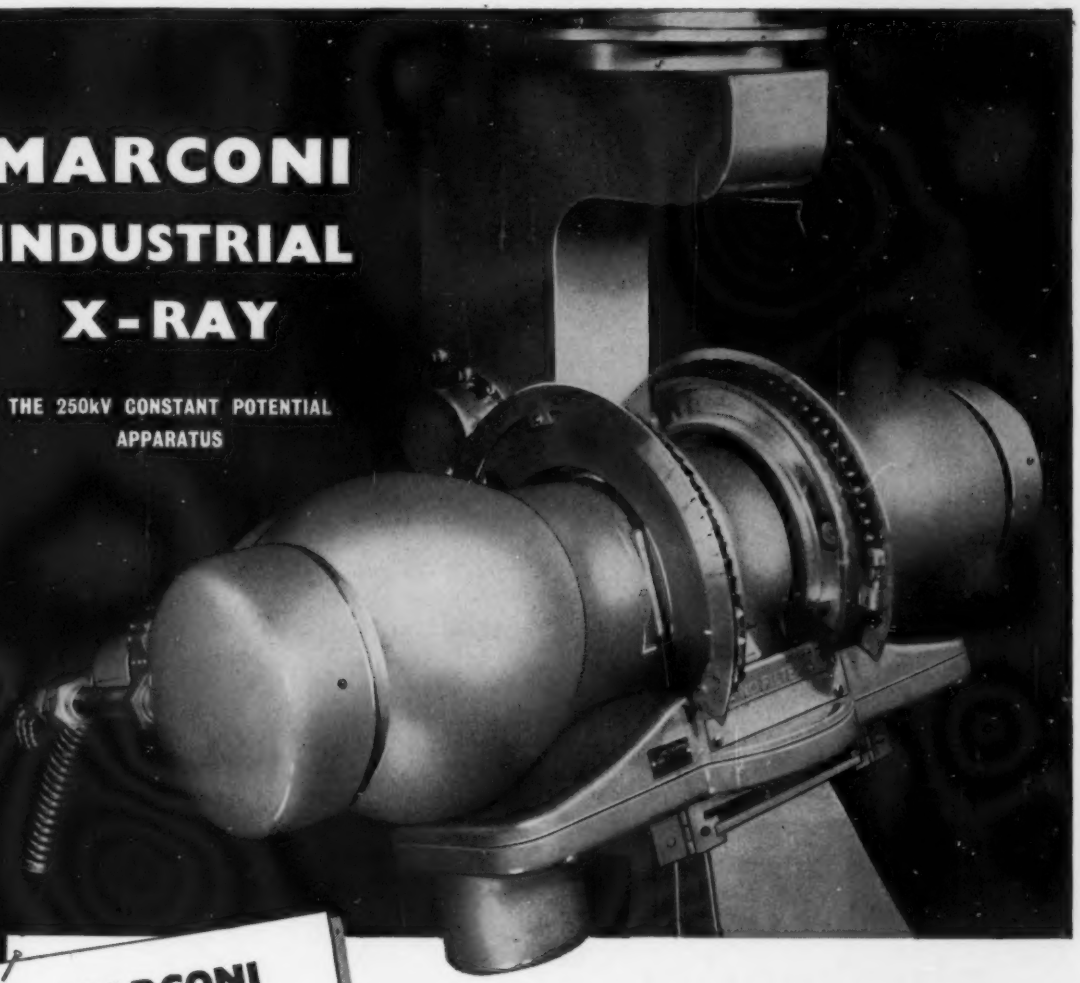
Devonshire House, Piccadilly W.1

Telephone : Mayfair 8867

Depots and Branches throughout the U.K.

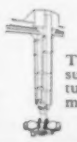
MARCONI INDUSTRIAL X-RAY

THE 250kV CONSTANT POTENTIAL APPARATUS

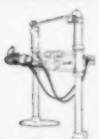


MARCONI for X-Ray

SOME MOUNTINGS FOR THE 250-kV TUBEHEAD *



Telescopic-suspension tubehead mounting



Double-column gantry tubestand

Dual-travel tubestand

* *Let Marconi engineers help you in your choice of mountings. In addition to those shown, other tubehead mountings are available to suit specialized requirements. Full details gladly sent on request.*

DESIGNED FOR A WIDE VARIETY OF APPLICATIONS IN THE ENGINEERING INDUSTRY

THE Marconi 250 kV Constant Potential X-Ray equipment is one of the most efficient and versatile 'inspection tools' at the service of the engineering industry. The basic apparatus comprises four main items—a high tension transformer-rectifier unit, a control unit, an oil circulator/cooler and the oil-cooled tubehead illustrated above.

The Kilovoltage range—which is from 30 to 250 kV in 2-kV steps—permits examination of components varying from plastic and aluminium items to ferrous sections more than three inches thick.

The scope of the apparatus has been extended still further by the development of a comprehensive range of tubehead mountings, which includes fully mobile and semi-mobile units, and suspension and static tubestand types, some of which are shown on the left. These mountings have been designed to meet industrial requirements and Marconi engineers are always available to recommend the most suitable installation, or suggest adaptations. For preliminary details of the Marconi 250 kV Constant Potential X-Ray equipment, please write for leaflet AQ22.

MAY WE ALSO SEND YOU PARTICULARS ABOUT OTHER MARCONI INDUSTRIAL X-RAY EQUIPMENT?

Please address enquiries to MARCONI INSTRUMENTS LTD. at your nearest office:

London and the South: Marconi House, Strand, London, W.C.2 Telephone: COVent Garden 1234

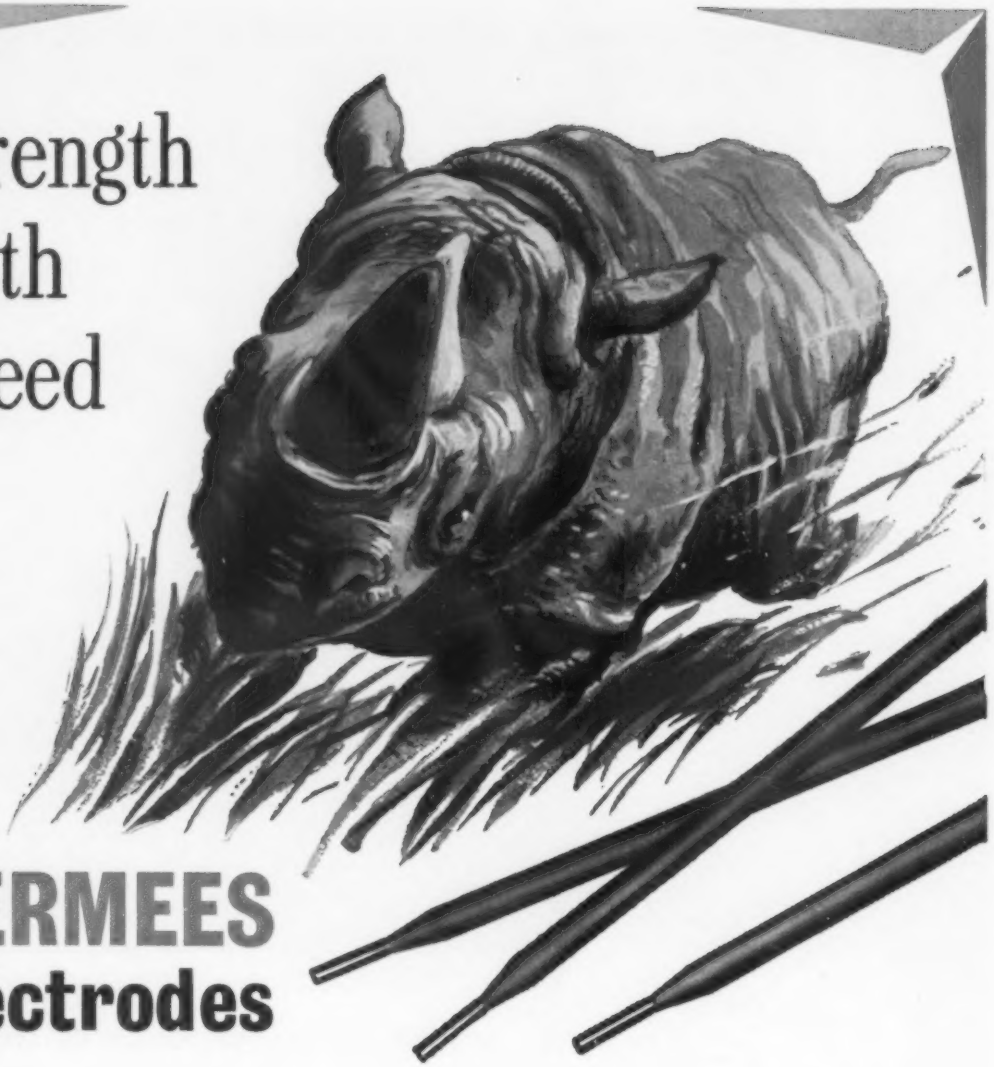
Midlands: Marconi House, 24 The Parade, Leamington Spa Telephone: 1408

North: 23/25 Station Square, Harrogate Telephone: 67455

Export Department: Marconi Instruments Ltd., St. Albans, Herts. Telephone: St. Albans 56161

IX22

Strength with speed



HERMEES electrodes

for

HEAVY SECTIONS
RESTRAINED JOINTS
HIGH TENSILE STEELS
CARBON & ALLOY STEELS

Great strength and amazing speed, characteristics of the rhinoceros, are outstanding qualities of 'ENGLISH ELECTRIC' HERMEES electrodes. The iron powder coating gives high deposition rates, ease of operation and quick deslagging.

Send for publication WA/141 to:
The English Electric Co. Ltd., Welding Electrode Division, Clayton-le-Moors, Accrington. Telephone: Accrington 3241.

'ENGLISH ELECTRIC'

welding electrodes and equipment

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

WAE.27

Welded by

JENKINS

OF ROTHERHAM

Arc welding on a large transformer tank.

Robert Jenkins & Co. Limited specialize in the welded fabrication of industrial plant. Modern techniques are used, in a large capacity factory, to produce storage tanks, ducting, fractionating columns and other processing and storage plant in mild steel, stainless steel, clad steel and aluminium. The petroleum, chemical, and nuclear power industries are among many served by Jenkins.

Welded fabrications and fusion welded pressure vessels to the requirements of Lloyd's Class 1, A.S.M.E. and A.O.T.C. codes and similar specifications.

ROBERT JENKINS & CO. LIMITED, ROTHERHAM

Telephone: 4201-6 (6 lines)

In a class of their own for economy and price!

WELDING INDUSTRIES

AIR-COOLED DIESEL WELDING PLANT

Model DA 123 (illustrated)

Powered by Lister 17 h.p. air-cooled diesel.

CAPACITY: 30–300 amps.

FUEL CONSUMPTION: 0·43 lb/BHP/hr. (full load)

No other mobile welding plant can compete with WELDING INDUSTRIES range: redesigned streamlined housings, latest cheap-to-run air-cooled diesels, new 'Flexitor' rubber suspension and many other unique features all add up to the finest value obtainable in Welding Plant to-day.

The existing range of plant includes:

DA	123 – 300 amps	–	Lister 17 h.p.	air-cooled diesel (ex-stock)
DA	134 – 400 „	–	„ 25½ h.p.	„ „
DW	134 – 375 „	–	„ 24 h.p.	radiator-cooled diesel
DW	144 – 450 „	–	„ 44 h.p.	„ „
DW	244 – 400 „	–	Ford 48 h.p.	„ „
TDW	163 { 600 „ single / 300 „ double }		Lister 54 h.p.	„ „

early delivery

Special sets can be manufactured to suit all requirements.

HOME COUNTIES
Messrs. Vales Plant (Register) Ltd.
14, Lower Grosvenor Place, London S.W.1

LANCASHIRE, CHESHIRE, YORKSHIRE, NORTH WALES
Messrs. William G. Search Ltd.
Whitehall Road, Leeds 12

WEST OF ENGLAND
Bristol Plant Hire Ltd., Bath Road, Bristol 4

SOUTH WALES
Messrs. O. L. Davies
Baglan Plant Depot, Port Talbot, Glam.

SCOTLAND
Messrs. Arc Manufacturing Co. Ltd.
Actarc Works, Nitshill, Glasgow S.W.3

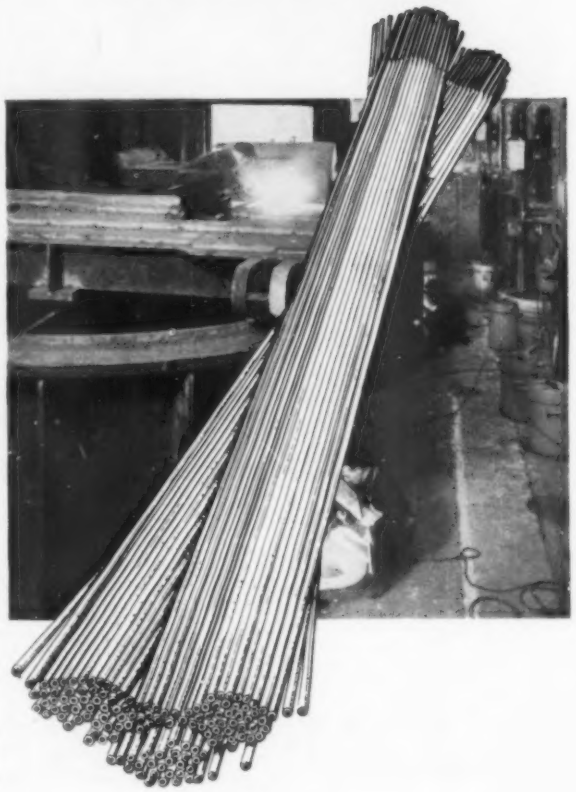
NORTHERN IRELAND
Robert Heslip Esq.
2–6, Georges St., Ravenhill Road, Belfast

EIRE
Messrs. Welding Services Ltd.
14a, Amiens Street, Dublin, Eire

Ask your nearest authorised dealer or write to Welding Industries for illustrated leaflet and prices

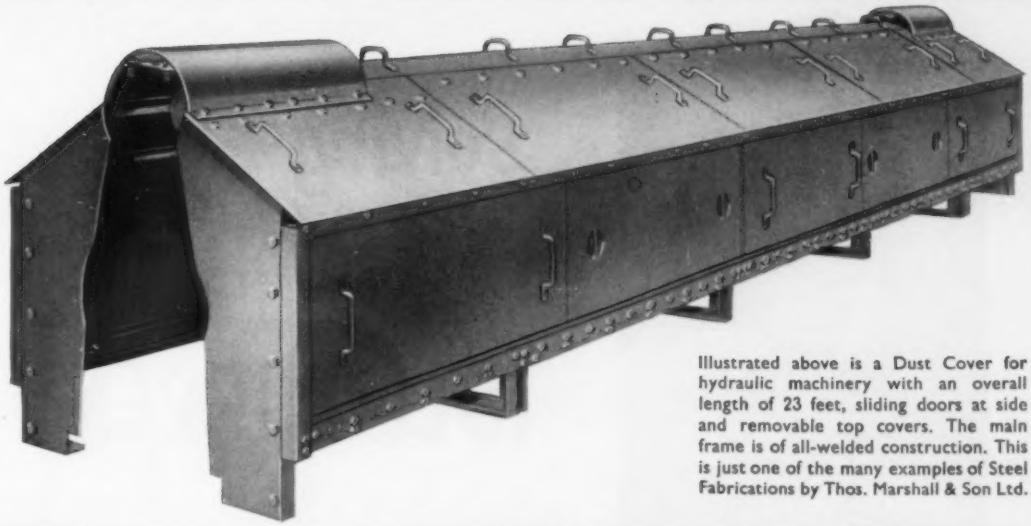
WELDING INDUSTRIES LIMITED
Blackswarth Road, Bristol 5
Phone 5-8408

Wire for the welding industry



Johnsons
WIRE FOR ELECTRODES

Richard Johnson & Nephew Ltd · Manchester 11
Tel.: EAST 1431



Illustrated above is a Dust Cover for hydraulic machinery with an overall length of 23 feet, sliding doors at side and removable top covers. The main frame is of all-welded construction. This is just one of the many examples of Steel Fabrications by Thos. Marshall & Son Ltd.

STEEL FABRICATIONS BY THOS. MARSHALL

& SON LTD.

WELLINGTON BRIDGE, LEEDS, 12 · 'GRAMS: 'CISTERNS' LEEDS, 12 · TEL. 32186 (5 lines)

---

* DESIGNED TO MEASURE SHORT PULSES OF HEAVY CURRENT

* MINIMUM OF 500 AMPS & MAXIMUM OF 100,000 OVER 6 SCALES

* NO INTERRUPTION OF WELDING OPERATION

HED

RESISTANCE WELDING CURRENT METER

* READINGS CAN BE TAKEN MINUTES AFTER WELD COMPLETED

* CAN BE USED WITH SYNCHRONOUS & NON-SYNCHRONOUS TIMERS

* MONITORS BOTH WELDING CURRENT & TIME SIMULTANEOUSLY

A new instrument of particular interest to every Welding Engineer

The standard instrument has six ranges covering readings of 500 to 100,000 amps. The readings are obtained by the use of toroids which can be split and placed around the heavy current conductor. Indication is stored enabling readings to be taken minutes after the weld is made.

Can be used with welders employing synchronous and non-synchronous and energy storage controls.

Write for full details and illustrated leaflet.

HIRST ELECTRONIC LTD.

GATWICK ROAD · CRAWLEY · SUSSEX

Telephone: Crawley 25721-2-3

Solving the problem of IDLE CURRENT !

to give you the same power for less money

The Problem: How to eliminate the idle current consumed by motors, welders, transformers, etc. In other words, how to improve Power Factor.

The Solution: BICC Power Capacitors: these idle current neutralizers improve the power factor of industrial loads with minimum inconvenience and expense.

The Advantages: Lower Electricity Bills — reductions in kVA demand charges or average power factor penalties are considerable; in fact BICC Capacitors usually pay for themselves in two to three years.

Reduced Current Loadings on cables, switchgear and transformers, enable additional loads to be connected or losses to be reduced.

BICC

POWER CAPACITORS

BICC 'MW' Capacitors are small, compact, highly efficient and easy to install. Our Publication No. 401 gives you further information. It's yours for the asking.

BRITISH INSULATED CALLENDER'S CABLES LIMITED · 21 Bloomsbury Street, London, W.C.1

THE INSTITUTE OF WELDING

54 Princes Gate, London, S.W.7

◆

COUNCIL and OFFICERS

PRESIDENT

E. Seymour-Semper

VICE-PRESIDENTS

W. Barr E. Fuchs
G. Roberts

PAST-PRESIDENT

J. Strong

HONORARY TREASURER

W. E. Harriss

Chairman of Executive Committee: R. E. G. Weddell

Representatives of Industrial Corporate Members

E. F. Burford, M.B.E.
C. Humphrey Davy
N. L. G. Lingwood
J. A. McWilliam
E. S. Waddington
Dr. R. Weck

Representatives of Fellows, Members, and Associate Members

D. J. W. Boag
V. W. Clack
F. Clark, M.B.E.
D. C. C. Dixon
J. A. Dorrat
E. Flintham
E. P. S. Gardner
S. H. Griffiths
Dr. N. Gross
D. B. Kimber
T. McIver
H. Martin

Representative of Companions

J. Hooper

Representative of Associates

A. Evitts

Chairman of B.W.R.A. Council: A. Robert Jenkins, J.P.

Chairmen of Standing Committees

Education Committee	Dr. E. F. Gibbs
Finance Committee	C. Humphrey Davy
Membership Committee	R. G. Braithwaite
Programme and Publications Committee	J. F. Lancaster
School of Welding Technology Committee	E. Seymour-Semper
Technical Committee	J. A. Dorrat

Representatives of Branches

Birmingham	W. R. Harper
East Midlands	A. H. Scothern
East of Scotland	J. F. Wheeldon
Eastern Counties	J. Edwards
Leeds	E. Rose
Liverpool	G. A. O. Pridgeon
Manchester	J. M. Whitworth
North Eastern (Tees-side)	J. W. Jackson
North Eastern (Tyneside)	W. R. Mellanby
North London	C. R. Thatcher
	L. C. Percival
Preston	F. Pilling
Sheffield	W. A. Jenkins, J.P.
Southern Counties	J. H. Gillespie
South London	Dr. M. C. Nickson
South Wales	I. B. Ford
South Western	A. J. Francis
West of Scotland	
Wolverhampton	M. R. Liddiatt

SECRETARY

G. Parsloe

BRITISH WELDING RESEARCH ASSOCIATION

29 Park Crescent, London, W.1

◆

COUNCIL and RESEARCH BOARD

PRESIDENT

Sir Charles S. Lillicrap, K.C.B., M.B.E.

CHAIRMAN OF COUNCIL

A. Robert Jenkins, J.P.

HONORARY TREASURER

W. E. Harriss

Members of Council

Sir Donald Bailey, O.B.E., J.P.
Prof. J. F. Baker, O.B.E., F.R.S.
Dr. R. Beeching
D. J. W. Boag
J. Brown
Dr. T. W. F. Brown, C.B.E.
H. G. Conway
C. Humphrey Davy
T. M. Herbert
E. J. Hill
F. C. S. L. Lewin-Harris
H. Pearson Lobnitz
Sir Andrew McCance, F.R.S.
Richard Miles
J. Mitchell, C.B.E.
Prof. Sir Alfred Pugsley, O.B.E., F.R.S.
L. Rotherham
E. Seymour-Semper
R. B. Shepheard, C.B.E.
C. M. Spielman, O.B.E., M.C.
T. Stevenson
J. H. N. Thompson, M.C.
Lt.-Col. J. F. Todhunter
W. T. Towler, J.P.
Dr. M. A. Vernon
Dr. E. G. West
J. M. Willey

Research Board

Dr. E. G. West (*Chairman*)
Dr. N. P. Allen, F.R.S.
Prof. G. Wesley Austin, O.B.E.
Prof. J. F. Baker, O.B.E., F.R.S.
Prof. J. G. Ball
W. Barr, O.B.E.
Dr. L. E. Benson
Dr. J. S. Blair
Dr. N. Booth
E. Fuchs
E. P. S. Gardner
A. H. Goodger
Dr. Nicol Gross
Dr. H. Harris
A. Robert Jenkins, J.P.
Dr. W. I. Pumphrey
Dr. L. Reeve
G. Roberts
Prof. E. C. Rollason
Dr. H. Sutton, C.B.E.
J. Turnbull
Dr. J. H. Weaving

DIRECTOR OF RESEARCH

Dr. Richard Weck

SECRETARY

A. O'Neill

FLEXIBLE

SHAFT

EQUIPMENT

B. O. MORRIS LTD. · MORRISFLEX WORKS, BRITON ROAD · COVENTRY

Telephone: 53333 (PBX) Telegrams: MORISFLEX, COVENTRY

PRODUCT OF THE Morrisflex GROUP

BRITISH WELDING JOURNAL

OFFICIAL JOURNAL OF THE INSTITUTE OF WELDING AND THE BRITISH WELDING RESEARCH ASSOCIATION

Incorporating the *TRANSACTIONS* of the Institute and *WELDING RESEARCH*

SEPTEMBER 1959
Volume 6 Number 9

Subscriptions
Members free:
Extra copies at 7*s*. 6*d*. each
Non-Members:
£5 per annum
Single copies 10*s*. each

Published Monthly

Editor-in-Chief: G. PARSLOE, M.A.
54 Princes Gate, London, S.W.7
(Knightsbridge 8556)

Executive Editor:
C. ROWLAND HARMAN, B.Sc. (Eng.)
Editech
6 Ridge End, Hook Hill Lane
Woking, Surrey
(Woking 2981)

Advertisement Manager:
G. S. HARTLEY,
54 Princes Gate, London, S.W.7.
(Knightsbridge 8556).

Note: Editorial contents copyright. The Institute of Welding and the British Welding Research Association do not hold themselves responsible for statements made or opinions expressed in articles appearing in this Journal.

CONTENTS

INSTITUTE OF WELDING

381 **A Practical Approach to Resistance Welding**
By K. H. McDowell and D. A. Weeks

396 **Automatic Vertical Welding**
By J. A. Lucey and D. D. Smout

BRITISH WELDING RESEARCH ASSOCIATION

406 **Effect of Compressed and Oxygen-Enriched Air on the Flammability of Fabrics**
By E. H. Coleman

411 **Compression and Tensile Loading Tests on Joists with Web Stiffeners**
By L. G. Johnson

421] **NEWS AND ANNOUNCEMENTS**

425 **CURRENT WELDING LITERATURE**

The Institute of Welding 54 Princes Gate, London S.W.7

British Welding Research Association 29 Park Crescent, London W.1

Cut and come again

In high production belt grinding, costs are determined by the speed with which the job is done; that is, the cutting efficiency of the abrasive belt.

Behr-Manning RESINALL METALITE BELTS

. . . offer in full the well-known advantages of resin bonding, standing up to all the heat and strain you can give them. They combine with this a remarkable resistance to wear. Try the effect of the exclusive double bond of thermo-setting resin and see the extra life it adds to the consistently fast cutting action. More important, try the effect on your overall grinding costs — and *profits*. See your Norton representative or write direct to us.

BEHR-MANNING Coated Abrasives

Made by Behr-Manning Ltd., Belfast, and marketed in the U.K. by their associated company

NORTON GRINDING WHEEL COMPANY LTD.

COATED ABRASIVES DIVISION, WELWYN GARDEN CITY, HERTS. Tel: Welwyn Garden 3484 (15 lines)

NORTON *and* BEHR-MANNING *factories also in Argentina, Australia, Brazil, Canada, France, Germany, Italy, Northern Ireland, South Africa and U.S.A.*

NORTON* ABRASIVES

* *Trade Mark of Norton Grinding Wheel Co. Ltd.*

NGW CM 150

Welding

TECHNOLOGY

A Practical Approach to Resistance Welding

By K. H. McDowell, L.I.M. *and D. A. Weeks*

During recent years the development of various types of resistance welding machine has been such that they now take an indispensible part in the manufacture of sheet metal products. In this paper the basic principles of resistance welding are briefly discussed, and the various processes and machines are described. The main purpose however is to examine the practical side of the subject with particular reference to the gas-turbine industry. Finally, the control and weld quality requirements of resistance welds are considered.

Basic Principles

FIGURE 1 is an elementary diagram of a simple spot-welding machine, and shows that a resistance weld is made by pressing two pieces of metal together while an electric current is passed through them to heat the localized contacting surfaces to the welding temperature.

The heat generated in a resistance weld is expressed by the formula:

$$H = I^2RT \text{ (Joule's Law)}$$

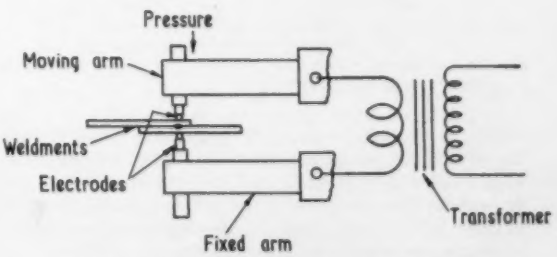
where H = heat generated
I = welding current
R = electrical resistance of the assembly
T = duration of current flow

This means that any variation in current, resistance of the assembly, and time of current flow, will effect the heat produced, and consequently the weld characteristics. It also happens that the pressure applied is important in this respect, because it has an influence on the resistance of the surface contacts between the parts and at the electrodes.

The pressure, current amplitude, and time of current flow can be fixed and then maintained at the welding machine. The electrical resistance of the pieces to be joined is a constant known factor, so that the variables now remaining which may influence the weld are:

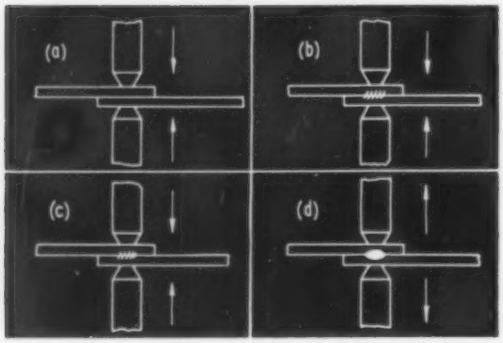
(*a*) Contact resistance between electrodes and work pieces to be welded
(*b*) Contact resistance between the work pieces themselves.

The surface condition of the work pieces will affect both these variables, so that the production of a uniform surface finish is essential to provide constant condition. It is also necessary to maintain the diameter of the electrode tips within certain limits, so that the pressure and current per unit area may also remain fairly constant.



1—*Elementary diagram of simple spot-welding machine*

Paper presented to the South Western Branch on 19th November 1958.
The authors are with Bristol-Siddeley Engines Ltd.



2—*Formation of spot weld;* (a) *Pressure applied, no current flowing;* (b) *with pressure still applied, current flows to cause local heating by resistance of interfaces;* (c) *current has ceased to flow and pressure forges pieces together;* (d) *weld has cooled, pressure is released, and electrodes are about to part*

Processes and Machines

It will be obvious that to make consistent and reliable welds, it is necessary to provide equipment that will ensure accurate and precise control. For many years resistance-welding equipment was designed on primitive lines, and put into production service without any form of control, reliance being placed on the skill of an operator to make a weld.

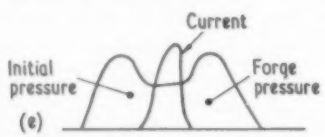
The gas-turbine industry demands the making of efficient and high-quality resistance welds, and so fully controlled equipment is essential. The following sections give some details of the various machines and processes used in this industry.

Resistance welding processes can be divided basically into five groups: spot, stitch, seam, projection, and butt.

Spotwelding

The materials to be welded are brought together under pressure by a pair of electrodes, and a heavy current is passed through them. This sets up local heat because of the resistance of the interface, causing the materials between the electrode tips to become molten, and join together (Fig. 2). The tips of the electrodes are water cooled to prevent similar local heating where they contact the components.

Spotwelding is a simple general purpose method of joining materials, ranging in thickness from less than



2e—*Typical pressure curve for welding light alloys. Current is applied during low-pressure cycle*

0·001 in. to about 1 in., the limitations being mainly the size of the machine available. Dissimilar gauges of mild steel, stainless steel, and heat-resisting alloys can be welded together, and although in general practice a ratio of 3:1 is normally the limit, some special applications involving the welding of 0·005 in. to 1 in. have been successful.

Tackwelding

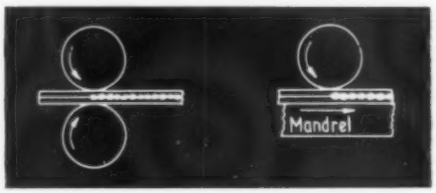
Tackwelding is similar to normal spotwelding, except that a lighter pressure and current is used, producing a weak spotweld (tackspot), which can be broken apart if needed without causing much damage to the work, thus allowing any errors of assembly to be rectified.

Stitchwelding

This is fundamentally the same as spotwelding, except that the forge time is greatly reduced, and the welding cycle is repeated automatically for as long as desired. The materials are moved through the electrodes during the period they are apart, by manual or mechanical means, causing one spot to overlap the previous one, thereby making a continuous weld. It is possible with mechanical means to make as many as 160 spots or more per minute.

Seamwelding

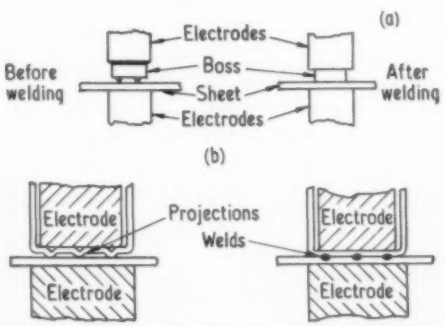
The materials are brought together under pressure by a pair of wheels, or in some instances a single wheel and a mandrel (*see* Fig. 3). The wheels rotate, and while the materials are moving through them a series



3—*Methods of forming seamwelds*

of high-current pulsations are applied, resulting in a continuous welded seam. The material may be overlapped sufficiently to produce a good lap joint, or overlapped only by about the thickness of the material being welded, when the resulting weld (which is called a mash seamweld) becomes almost a butt joint. Another method is to butt the materials together, and to lay a thin strip of similar material on each side of the joint, which is then seam welded, the additional material acting as a filler wire.

Some refinements of seamwelding include apparatus to enable the wheels to become stationary while the current is still flowing through the electrodes and



4—*Typical applications of projection welding:* (a) *Set-up for attaching bosses to sheet;* (b) *set-up for joining* **U***-shaped channel to sheet*

work. This results in a series of overlapping spots, each of which has had time to cool, forming a continuous weld. There is also an electronic counter unit to enable any predetermined number of pulses to be made at any one time while the wheels are stationary. These devices help greatly to reduce distortion during welding.

Projection welding

One of the two materials to be welded has one or more projections or raised portions incorporated in its design. When pressure is applied to the electrode or jig, as the case may be, to sandwich the two materials, the current passes through these projections, causing them to collapse owing to heat and pressure, and to form a weld, as shown in Fig. 4.

Butt welding

This group can be split into three further basic divisions: Plain butt welding, flash butt welding, and percussion welding. The latter, although not a resistance weld in the true sense of the word, is accepted generally as such.

Plain Butt Welding—The two materials for welding are clamped in copper alloy jigs and are brought together under pressure (Fig. 5*a*). A current is then passed through the abutting ends, which heats them up to forging temperature. The current is then switched off, and a higher pressure is applied, which forges the materials together.

Flash Butt Welding—The beginning of the process is like that for plain butt welding, but while the current is still flowing the components are separated, producing an arc which makes the ends of the materials molten; they are then brought together again, and an up-set pressure is applied to forge the materials together (Fig. 5*b*).

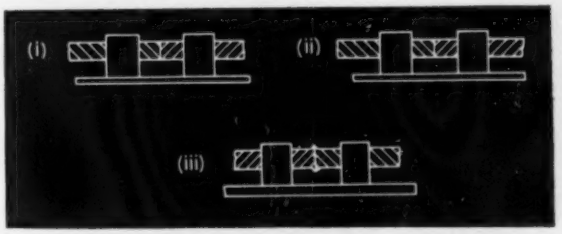
Percussion Welding—The two materials to be welded are again clamped with a space between them in jigs, usually made of copper alloys, and a charged capacitor is coupled across them (Fig. 5*c*). The components are then brought together rapidly, and when the air gap between them is about $\frac{1}{16}$ in. the high voltage of the capacitor breaks down the resistance of the air gap and causes an arc to be established between the parts. This arc causes the metallic surfaces to melt, and the extremely rapid motion brings them into percussive engagement before they cool, thereby effecting the weld.

Choice of machine

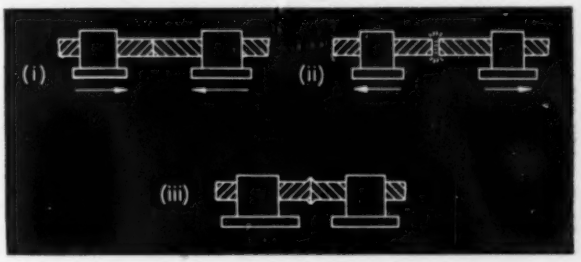
The choice of suitable welding machines depends on several factors:

(i) Number of components to be welded
(ii) Shape and size of components
(iii) Existing welding plant or availability of new plant
(iv) Type of materials to be welded
(v) Type of welding required.

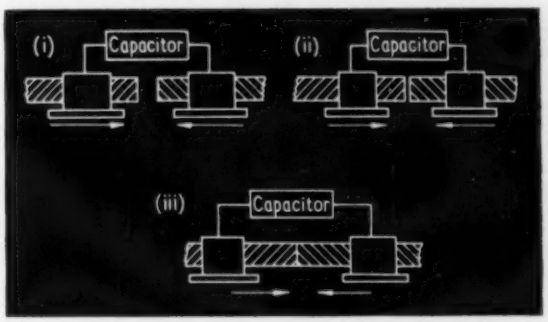
If thousands of any one particular component have to be produced, such as in the automobile industry, it will be beneficial to have new plant specially designed to carry out welding at high speeds and with the least amount of preliminary jigging and tacking. However, if the jobs are few and varied, a small universal machine will probably suffice. If existing plant is not



5a—*Plain butt welding: (i) Materials brought together under light pressure; (ii) current flowing and abutting ends heating up; (iii) current has ceased to flow and heavy pressure forges the materials together*



5b—*Flash butt welding: (i) Materials pressed together and current flowing; (ii) pieces draw apart to form arc; (iii) current ceases to flow and parts are brought together under an upset pressure to form weld*



5c—*Percussion welding: (i) Materials clamped and moving towards each other; (ii) capacitor discharging while parts still moving; (iii) capacitor discharges while parts are brought together under pressure and cooled to form weld*

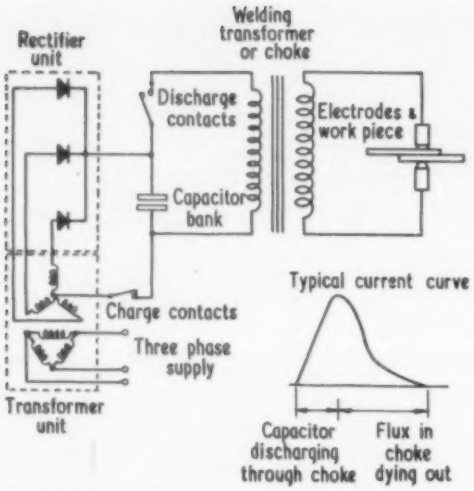
suitable, there is a possibility of modifying it to suit the type of work envisaged.

There are roughly three types of welding plant used in Britain:

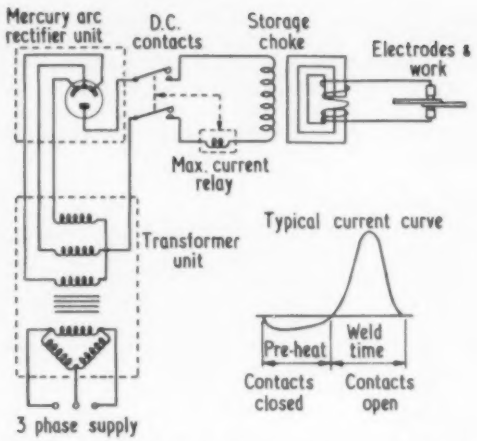
(*a*) Single-phase a.c. machines
(*b*) Direct current machines—(i) Capacity discharge; (ii) inductance storage
(*c*) Three-phase machines.

Single-phase a.c. welding machines comprise the bulk of British welding equipment, and are suitable for most types of welding. The line power demand, however, is heavy and unbalanced, and where the local authority demands power-factor corrections, the initial outlay may be high.

The capacitor-discharge type of d.c. machine (Fig. 6*a*) draws a small rectified power demand off a 3-phase supply to charge banks of capacitors. These



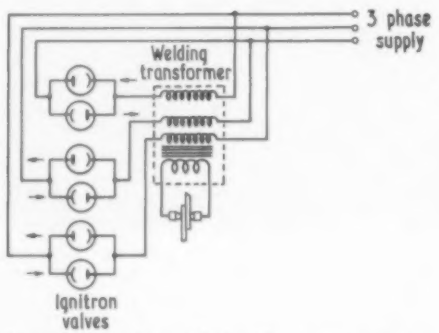
6a—*Simplified diagram of capacitor-discharge type machine*



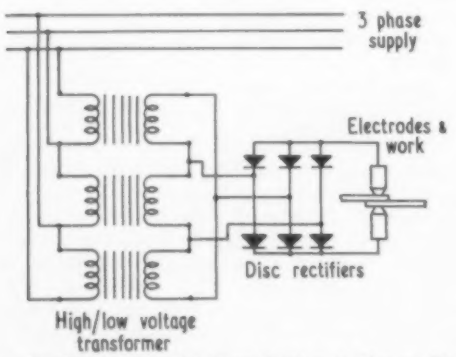
6b—*Simplified diagram of induction-storage type machine*

are then discharged rapidly through the welding choke or transformer, causing heavy currents to flow in the secondary side of the machine.

In the inductance-storage type (Fig. 6*b*) a 3-phase supply is rectified and passed through the main welding choke; when the choke has the preset amount of stored energy a magnetic trip cuts off the power supply, and the rapid collapse of the magnetic field in the choke induces high current in the secondary windings of the welding machine.



7a—*Diagrammatic scheme of 3-phase frequency-converter machine*



7b—*Simplified circuit of 3-phase dry-disc rectifier machine*

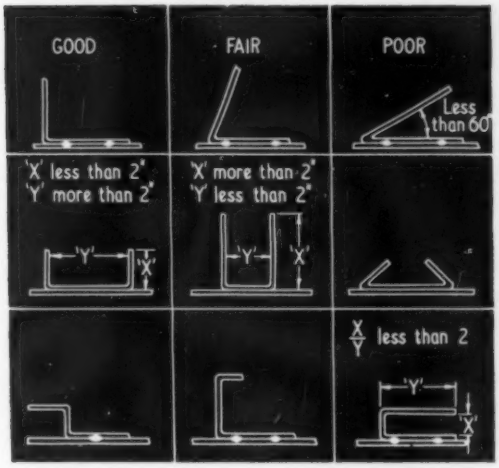
In the United States there are other forms of d.c. plant, such as machines which obtain their power from banks of batteries that are being constantly charged from motor-driven charging sets, or even directly from motor generator sets. These types of machine, however, are mainly found in districts where the electrical power supply is small or non-existent.

The development of the 3-phase or modulated wave welder has been rapid in the past five or six years, and although a great deal of welding has been carried out on these machines, both in the United States and on the Continent, they are only just coming into general use in Britain. The most common type is the 3-phase frequency-converter system (Fig. 7*a*), where the welding transformer has three primary windings and one low-voltage winding. By suitable control each phase is allowed to pass current through one of the primary windings, thereby inducing a heavy current into the secondary winding. The direction of current flow through the primary windings is reversed periodically, at a pre-selected rate, so that the magnetic flux also is reversed, eliminating the possibility of the welding transformer core becoming saturated.

Another type of 3-phase machine used successfully in the United States is known as the dry-disc rectifier type (Fig. 7*b*). Transformers supply power to high-current, low-voltage rectifiers of the magnesium/copper sulphide type, which in turn deliver direct current direct to the weld. These rectifiers are relatively small and being of robust construction they require little maintenace. The size and shape of the machine is similar to a single-phase machine. The advantages of all 3-phase machines are that they draw a balanced load from the supply, and that the welding current output can be controlled both in magnitude and duration with ease and accuracy.

Design Considerations

As in all other methods of joining, care must be taken that the right combination of component design and type of machine used is correct, or poor welds may be the result. In the spot, stitch, seam, and most



8—*Typical examples of good and bad joint design*

of the projection welding processes joints are of the lap variety, and therefore allowance must be made for the correct amount of overlap, the spacing of welds, and the accessibility of the particular area to be welded. Some examples of good and bad joint design are shown in Fig. 8. It is surprising how often the design of a component has either to be altered to accommodate resistance welding operations, or the method of joining changed to, say, a fusion welding method. The joint preparation is also important, and Table I indicates the average spot diameter and edge-to-weld distances for various materials and sheet thicknesses.

To arrive at the welding techniques needed to set the machines for production, the physical characteristics of the materials to be welded must be considered. The most important factors of some of the metals and alloys used in the gas-turbine industry which affect the resistance weldability and machine capacity, are given in Table II. Metals of the stainless steel type and nickel alloys have a high electrical resistance; light alloys have low resistance, and materials of mild steel type occupy an intermediate position. This indicates, to some degree, that very high currents are required to weld light alloys, compared with those needed for mild steel or stainless steels.

Table I

Average spot diameters and edge-to-weld distances

Material	*Sheet Thickness*		*Dia. or Width of Weld,*	*Minimum Pitch,*	*Minimum Distance to Free Edge,*
	s.w.g.	*in.*	*in.*	*in.*	*in.*
Mild Steels	24	0·022	0·150	0·350	0·150
	22	0·028	0·150	0·350	0·150
	20	0·036	0·187	0·380	0·187
	18	0·048	0·218	0·400	0·218
	16	0·064	0·250	0·750	0·250
	14	0·080	0·280	1·000	0·280
	12	0·104	0·375	1·250	0·375
Stainless Steels	24	0·022	0·125	0·350	0·125
	22	0·028	0·150	0·350	0·150
	20	0·036	0·187	0·450	0·187
	18	0·048	0·250	0·625	0·250
	16	0·064	0·250	0·750	0·250
	14	0·080	0·312	0·873	0·312
	12	0·104	0·375	1·000	0·375
Light Alloys	24	0·022	0·150	0·375	0·150
	22	0·028	0·187	0·500	0·187
	20	0·036	0·200	0·500	0·200
	18	0·048	0·250	0·750	0·250
	16	0·064	0·300	1·000	0·300
	14	0·080	0·350	1·125	0·350
	12	0·104	0·375	1·250	0·375

A further factor affecting weldability is the thermal conductivity. For instance, the light alloys have a high thermal conductivity, and thus heat is rapidly conducted away from the weld interface, which causes rapid weld solidification. This effect, incidentally, is the reason for using a weld cycle called 'programme control', *i.e.*, a post-heating current, to decrease the rate of cooling during solidification, and so reduce shrinkage cracking and porosity. Welding times are also kept short to minimize conduction losses.

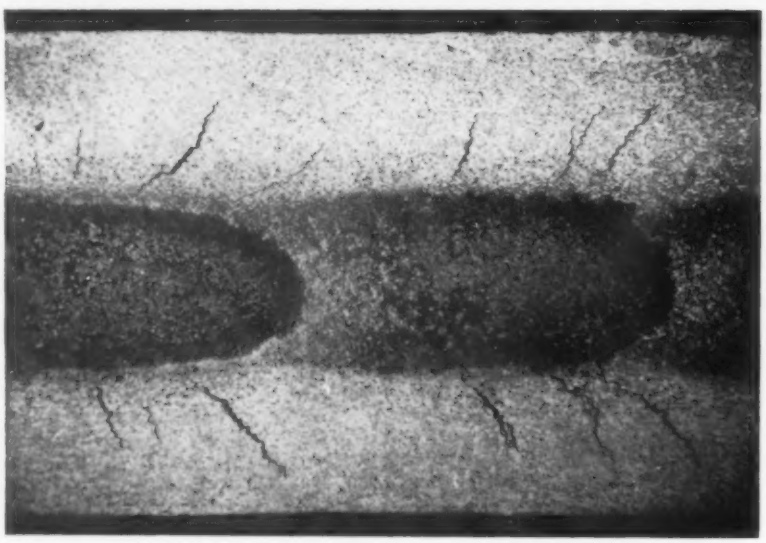
Resistance welding is essentially a local heating operation, involving local expansion and contraction, so that such factors as the specific heat and thermal expansion of metals are important. Materials of high specific heat will require more heat to raise them to welding temperature than those of low specific heat.

Table II

Physical properties of several materials

Metal	*Melting Range*	*Coeff. Linear Expansion,*		*Physical Properties* *Thermal Conductivity, Cal/sq.cm/sec/°C./cm*		*Specific Gravity*	*Specific Heat,*	*Electrical Resistivity,*
	°C.	*°C.* $\times 10^{-6}$					*cal./°C./cm*	$\mu\Omega$*/cu.cm*
		0–100°	0–500°	20°	500°			
Aluminium	659	24	29	0·52	0·63	2·79	0·24	2·87
Duralumin Type	530–610	23·7	—	0·30–0·45 (0°C)		2·82	0·24	3·3–5·3
Low-carbon Steel	1500–1540	12·6	14·4	0·193 (100°C)	0·109	7·90	0·155	19·9
Stainless Steel 18/8 Type	1400–1420	17·3	18·4	0·039 (100°C)	0·0515	7·92	0·12	70
Nimonic 75	1390–1420	—	14·7	0·032 (100°C)	0·071 (900°C)	8·35	0·11	109
Nimonic 90	1360–1390	—	14·2	0·030 (100°C)	0·069 (900°C)	8·27	0·103	115
Titanium	1660	8·9	9·7	0·040	0·0364	4·51	0·126	55·4

9—*Typical shrinkage crack on spot weld nugget* ×20



10—*Grain boundary eutectics which appear to be cracks* × 20

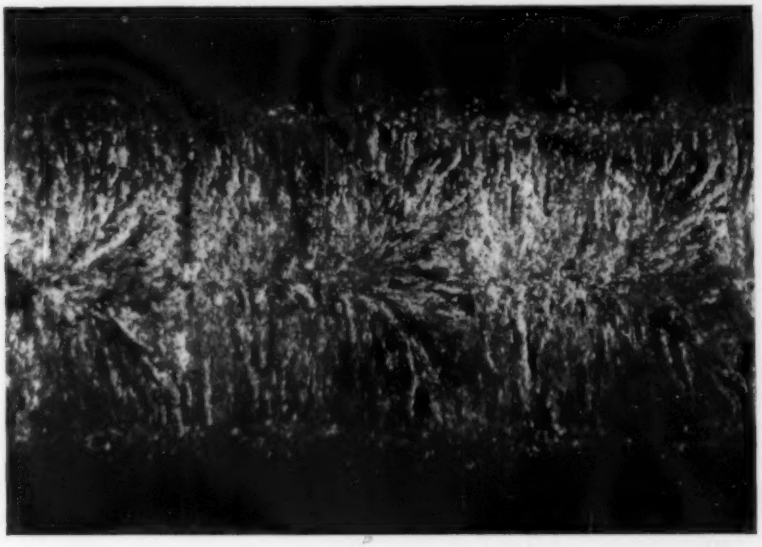
Residual stresses may be imposed owing to expansion and contraction taking place largely under restraint. These may require further treatment, depending on the extent of heating, and the design and composition of the welded assembly.

Metallurgy of Resistance Welding

Metallurgical considerations

Heating a metal during welding affects its structure, depending on the temperature, the time the metal is maintained at that temperature, and the composition of the metal. Similarly, the rate of cooling from the welding temperature may also influence the resulting weld structure. From the metallurgical aspect the best welding cycle is that which produces the least disturbance in the properties of the weld as compared with that of the unwelded material. For instance, the extent of the heat-affected zone will depend largely on the energy input, but more particularly on the welding time. Thus, the use of short welding times for any material will obviously reduce the extent of the heat-affected zone. But with low-alloy steels and other heat-treatable alloys, although the short welding times will restrict the heat-affected zone, they will increase the rate of cooling, and so affect the hardening of the weld. Relatively long welding times, on the other hand, will reduce the rate of cooling and, in some instances, the weld hardness, but may give rise to excessive indentation.

Some of these metallurgical difficulties associated with various materials used in the gas-turbine industry, will now be discussed.



11—*Spotweld in Cr–Mo low-alloy steel* ×20

Light alloys

Although the light alloys generally require high currents and short weld times they have a very short plastic range, *i.e.*, the temperature range between initial melting and final melting is small, and a close control is necessary over the machine settings. Small variations in current time and pressure may produce relatively large variations in weld size.

Again, weld solidification is rapid, and this increases the tendency to form shrinkage cracks and porosity. The former type of defect may extend beyond the weld nugget, but is usually radial and does not reach the circumference. A typical example is shown in Fig. 9. If the current or the weld time are excessive, overheating can result, producing streaks that look like cracks, but which are actually the eutectic pressed into the molten grain boundaries, as shown in Fig. 10. Porosity is also associated with overheating. Provided that these defects, cracks, and porosity are confined within the weld zone they are usually accepted, as there appears to be no evidence that they have any detrimental effect on the strength of the welds.[1]

For spotwelds in material of the Duralumin type, corrosion is liable to occur preferentially in the area round the most severely heat-affected spots, owing primarily to the precipitation of $CuAl_2$. In the aluminium coated type of alloy this trouble is eliminated, provided that the weld nugget does not reach the outer surface of the sheets. Resistance welded alloys containing an addition of magnesium (*e.g.*, Mg.7), are very resistant to corrosion. It must be borne in mind that one of the most serious disadvantages in the welding of heat-treated or work-hardened light alloys is the appreciable softening that occurs in the heat-affected zones, for it is not possible to resistance weld these alloys at temperatures below the softening points.

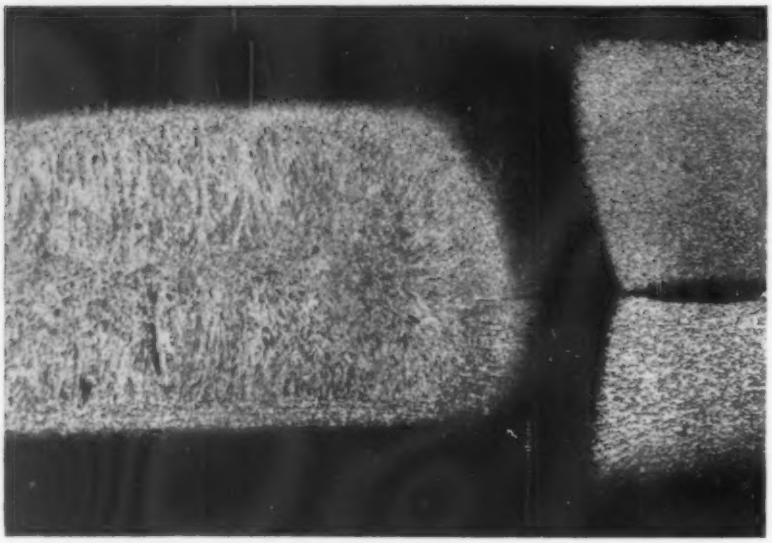
Other less common faults associated with light-alloy welding are (i) tip pick-up, (ii) burn marks, (iii) holes through the work, and (iv) extruded weld metal. Usually tip pick-up and burn marks result from the electrode tips being too small for the gauge of materials, inadequate cooling of electrode tips, excessive current, or dirty material. The principal causes of holes being burned through work are foreign matter between sheets or embedded in electrodes, poor fit of sheets, or the operator having hit a drilled hole.

Cracking, porosity, and other effects can be controlled by the use of special machines, but the relationship between current and pressure invariably needs particular attention to attain optimum results. As already explained, such effects as programme control and weld current decay represent great strides in the production of quality welds. It should be noted that the seam-welding of aluminium and its alloys is a production process, and the main difficulty of electrode wheel pick-up has been overcome by using electrode material of high conductivity.

Steels

For mild steels, which do not suffer from excessive weld hardening, the weld cycle can be very simple. Provided that sufficient current is available, and the pressure ensures reasonable contact at the interface, there is quite a latitude in the permissible weld time. Difficulties can occur, however; for example that arising from the use of 'uniblasting' before welding. The surface of the metal is coated with aluminium oxide, which greatly increases the resistance and so prohibits welding under normal conditions. There is, of course, a limit to which hardening of the weld and adjacent metal may be tolerated.

With steels of higher carbon content, above say 0·18%, or those with low alloying additions of chromium, nickel, and manganese in particular, a considerable variation in properties may be obtained for different rates of cooling. The hardening effect will increase as the rate of cooling increases, so that high rates of cooling may give rise to welds of relatively high tensile strength and poor ductility. The weld illustrated in Fig. 11, of T.53 type steel (Cr-Mo low alloy), was extremely brittle. In extreme cases the metal adjacent to the weld may show 'quenching'



12—*Typical seamweld in martensitic stainless steel sheets* ×20

cracks arising from the volume changes associated with the formation of the hardened structure and the cooling shrinkage of the weld. These high-tensile and low-alloy steels are best welded as quickly as possible, allowing a definite time off in which the weld can cool rapidly to produce a hard and brittle transformation product. The latter is then tempered by means of a second current impulse of smaller magnitude than the first. In a series of investigations on Ni-alloy steels, not only were satisfactory spotwelds produced, but it was found that all of the usual heat-treatments, such as tempering, austempering, quenching, and grain refining, could be performed on the weld in the welding machine in a relatively short time, by the use of electronic control mechanisms.[2]

At the authors' works a separate tempering operation by conventional means is carried out on most low-alloy steel assemblies welded in the hardened and tempered condition. Sometimes the components are welded in the annealed condition, and are subsequently subjected to a full heat-treatment process.

Stainless steels

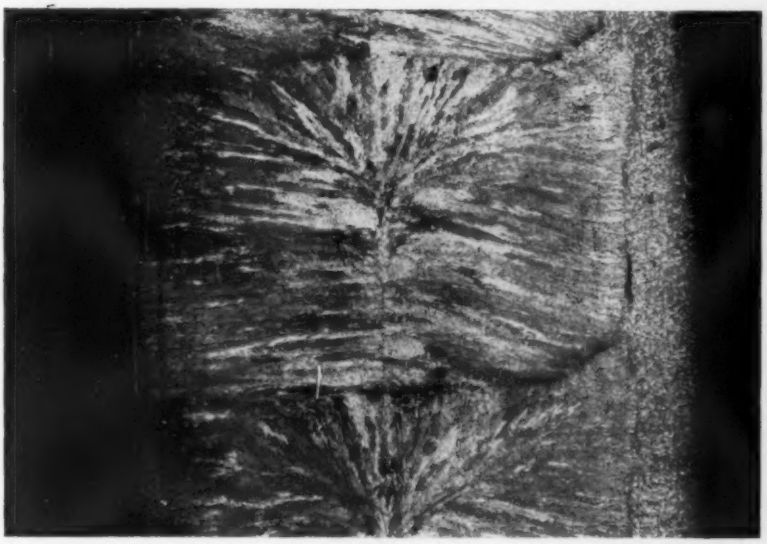
Martensitic Stainless Steels—A considerable amount of experience has been obtained on the resistance welding of a particular type of martensitic stainless steel, with approx. 0·1% C, 11% Cr, and other alloying elements. It has good corrosion and heat resistant properties, and in the fully heat-treated condition it attains reasonably high physical properties. The composition is balanced so that a part of the structure of the alloy is soft ferrite, which exerts a significant effect by decreasing the overall hardness, and reducing the susceptibility to cracking. In addition, the carbon is kept low to control the degree of hardness developed in the martensitic structure.

These characteristics are significant in resistance welding, but short welding times and high electrode pressures are still desirable to reduce any peak hardening tendencies and grain growths in material adjacent to the weld. A typical seamweld of a sheet-to-sheet material is shown in Fig. 12. The use of a post-heating current, as explained in the welding of high-tensile and low-carbon steels, is possible for this type of stainless steel, so as to obtain a tougher and more ductile weld without recourse to conventional heat-treatment processing. Generally, however, most units in this material contain parts welded by fusion methods, in addition to resistance welding, and post heat-treatment by conventional means is carried out.

Austenitic and Heat Resisting Stainless Steels—The most widely known alloy of this series is the 18% Cr-8% Ni type, which has been associated with the much publicized phenomenon 'weld decay'—a tendency towards intergrannular corrosion. However, present trends are to use stabilized materials, most commonly titanium and niobium. If there is enough of the stabilizing element present to combine with all the carbon, no chromium carbide is formed. Consequently, there is no depletion of chromium near grain boundaries, and the material is not susceptible to intergrannular corrosion.

The resistance welding of unstabilized 18/8 stainless steels is not always associated with tendencies to intergranular corrosion. Time is an important factor in carbide precipitation, and the shorter the time of heating the higher is the temperature at which precipitation begins. Fortunately, 18/8 steels have a lower heat conductivity and melting range than, say, mild steel. They also have an electrical resistivity approx. six times that of mild steel. Consequently they require less heat input, and so with short welding times a reduced heat-affected zone is achieved which will not reach the outer surfaces of the overlapping sheets. Unless the corroding agent penetrates between the sheets there is no intergranular corrosion round the spotwelds in service. In addition, the high rates of cooling possible with 18/8 steels result in the absence of weld cracking tendencies. Figure 13 illustrates the possibilities of resistance welding 18/8 steels, for it represents a multi-thick 18/8 seamweld.

The higher alloyed austenitic Cr-Ni steels of the 25/20 type have characteristics similar to those of the 18/8 variety. The increased alloy contents reduce the



(*Left*)
13—*Seamweld in multi-thick 18/8 stainless steel* ×20

(*Below*)
14—*Faulty seamweld in Nimonic 75 sheet* ×10

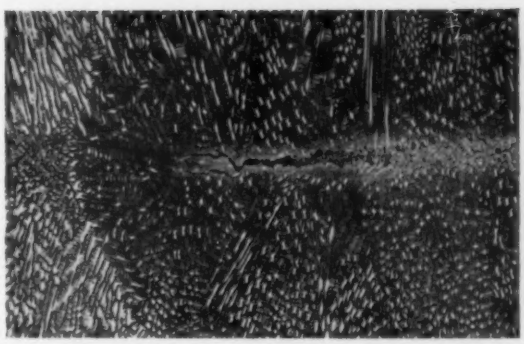
15—*Seamweld in Nimonic 90 sheet* ×100

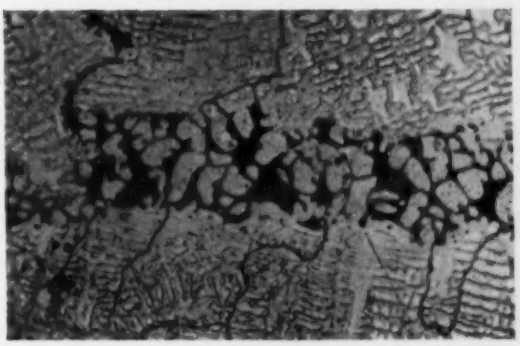
16—*Enlarged dendritic portion of Fig. 15* ×680

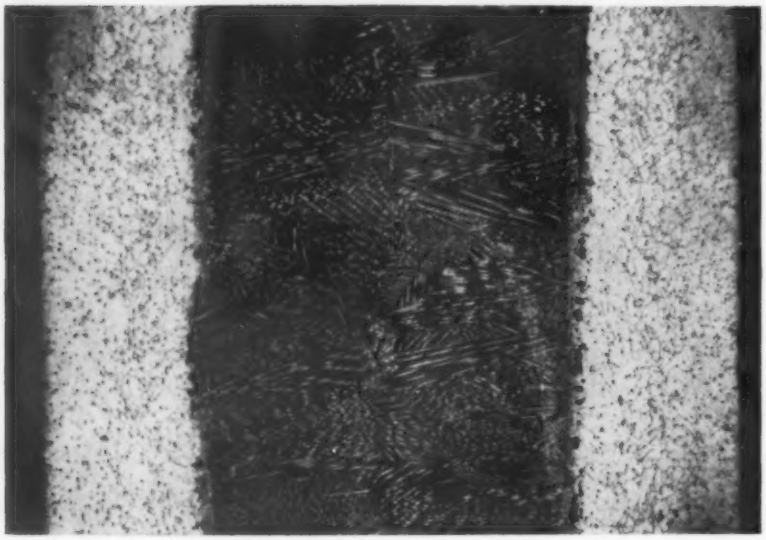
speed of carbide formation, and also provide additional chromium to combat depletion in the event that carbides precipitate. Such steels are broadly classified among the 'heat resisting steels'. Generally, the composition is deliberately modified by the addition of such strong 'ferrite formers' as silicon, molybdenum, or tungsten, to give a duplex structure and so increase hot-cracking resistance. The amount of ferrite present, however, is controlled to avoid the formation of excessive sigma-phase when the metal is heated at temperatures around 650°–900°C.

Nickel Base Alloys

For highly stressed parts, where the operating temperature is above about 700°C. more complex alloys have been developed. The nickel-base alloys are typical of those super-alloys that will retain their strengths at high temperature without deformation from creep. Compared with mild steel they have a high electrical resistance, a lower thermal conductivity, much higher mechanical strength retained at greater temperatures, a shorter range at which the material is in a plastic condition, and a greater coefficient of expansion. These features exert a great influence on the resistance welding settings, and in the first place high electrode pressures are needed to ensure satisfactory forging of the weld. Consequently, surface resistance decreases and higher currents are required to maintain equal fusion zone sizes. This increase in weld current may cause expulsion of molten metal from the weld. According to the thermal gradient present, porosity and even cracking may result, as shown in Fig. 14. If the thermal gradient is low from the edge of the fusion zone to the sheet surface, metal may be expelled along cored grain boundaries to form intergranular rivers.[3] At low magnification, structures containing these rivers appear to contain intergranular cracks, but higher magnification shows that this area is not cracked, but is completely dendritic. These effects are illustrated by the seamwelds in Nimonic 90 sheet (Figs. 15 and 16).







(*Left*)
17—*Seamweld in Nimonic 100* ×20

(*Below*)
18—*Spotweld in c.p. titanium, showing apparent high penetration but lack of fusion* ×10

The presence of complex carbides and compounds in these nickel-base alloys may lead to a welding difficulty where intergranular cracking can occur in the heat-affected zone of a weld. It has been suggested[4] that this defect is due to a low melting-point eutectic in the grain boundaries succumbing to the heat effect of welding.

These characteristics show that careful consideration has to be given to the initial preparation of welding techniques for nickel-base and other high-strength heat-resisting alloys. A further essential is the availability of welding machines capable of providing all the necessary variables of pressure and time cycles and heat control. However, great achievements have been made in this field in recent years, as shown by the seamweld in Nimonic 100 (Fig. 17).

Other high-temperature materials have also been investigated, and have been found to have good resistance weldability. Precipitation hardening stainless steels, boron-containing stainless steels, and complex alloys such as G.56 and Esshete 1250, have given excellent results.

Titanium

Up to the present time, production shop experience has been confined to the welding of commercially pure titanium. The low thermal and electrical conductivity and low coefficient of expansion of this metal facilitates the formation of sound spot and seam-welds. The closeness of the two sheets to be welded and the relatively high speed of welding are adequate safeguards from the contamination of the nugget during local melting. High penetration is considered to be a normal characteristic, but differentiation between the heat-affected zone and weld nugget is difficult, since the large grains of the former grow with the melt to form the dendrites. Figure 18 shows a titanium weld with an apparent high penetration, but the lack of fusion at the interface indicates a small fused zone.

The best combination of properties results from fairly short weld times at high current. Short times minimize grain growth and contamination, while restricting the size of the heat-affected zone. Excessive tip pressures tend to cause flashing and sticking, but welding techniques for titanium are not usually critical, and the production of resistance welded titanium parts are virtually commonplace. Flash welding also is being successfully carried out under production conditions.

Commercially pure titanium consists essentially of a single-phase, and alloys of this type, designated alpha alloys (*e.g.*, with 5% aluminium–2½% tin), can be welded without any harmful effect on their mechanical properties. Encouraging experimental work has been carried out on the welding of alpha/beta alloys, such as the 6% Al–4% V and 16%V–2½% Al types, and there is a possibility that post-weld heat-treatment will widen the range of weldable titanium alloys.[5] A high-strength beta-alloy containing 13% V–11% Cr–4% Al, is said to have good welding characteristics.[6]

Dissimilar metals

Although, so far, the union between similar metals has been considered, there are instances where dissimilar metals require to be joined. Most applications are highly specialized, and must be judged on the basis of each individual case. The greatest difficulty to be expected is when the combination mixed in the weld nugget forms undesirable characteristics. Generally, any procedure which reduces the mixing of the two base materials in the nugget is helpful. High welding current with short times tends to do this, and the use of dissimilar electrode material is usually beneficial.

19—*Section of sound seamweld between mild steel and 18/8 stainless steel* ×20

20—*Weld between Nimonic 75 and Nimoply* ×20

When the electrical resistance of the two materials and their melting points vary widely, a nugget is sometimes formed entirely in the high-resistance material, and no joint is made. High-resistance electrodes against the low-resistance material, or small diameter electrodes against the low-resistance material, or larger diameter electrodes against the high-resistance material, or a combination of both, will pull the nugget across the interface.

One combination frequently used is that of stainless steel to mild steel. The conditions to bear in mind here are that stainless steel heats more quickly than mild steel with a given current, and forges less easily. Thus, a lack of heat in the mild steel could result in heavy indentation in association with a poor weld. The weld must be made in the shortest possible time, and the pressure should be somewhere between that normally used for stainless steel and that for mild steel. Figure 19 shows a section of a sound seamweld between mild steel and 18/8 type stainless steel. There is no interaction between the two materials, and the weld looks like a braze. The heavy black line at the interface has been caused by a preferential attack on the mild steel.

Various types of stainless steel can be welded to one another, and to most of the nickel-base and other heat-resisting alloys, without difficulty. An interesting example is the welding of Nimonic 75 to Nimoply (copper sandwiched between Nimonic 75), the latter being material suitable for high-conductivity requirements. As Fig. 20 shows, the joining takes place between the Nimonic 75 materials, and efforts to increase the weld to include the copper result in unsatisfactory welding, owing to excessive indentation and expulsion of metal. In fact, the inclusion of the

Table III
Combination of materials for welding

	Aluminium and Alloys	Mild Steel	Stainless Steels	Nickel and Alloys	Brass	Copper	Magnesium and Alloys	Plated Mild Steel	Titanium	Phosphor Bronze
Aluminium and Alloys	G	P	I	I	FS	FS	G	I	I	FS
Mild Steel		E	F	F	P	P	P	F	I	P
Stainless Steels			E	G	P	P	I	P	I	P
Nickel and Alloys				E	P	P	I	P	I	P
Brass					F	F	P	P	I	F
Copper						P	FS	P	I	P
Magnesium and Alloys							E	I	I	P
Plated Mild Steel								F	I	P
Titanium									E	I
Phosphor Bronze										G

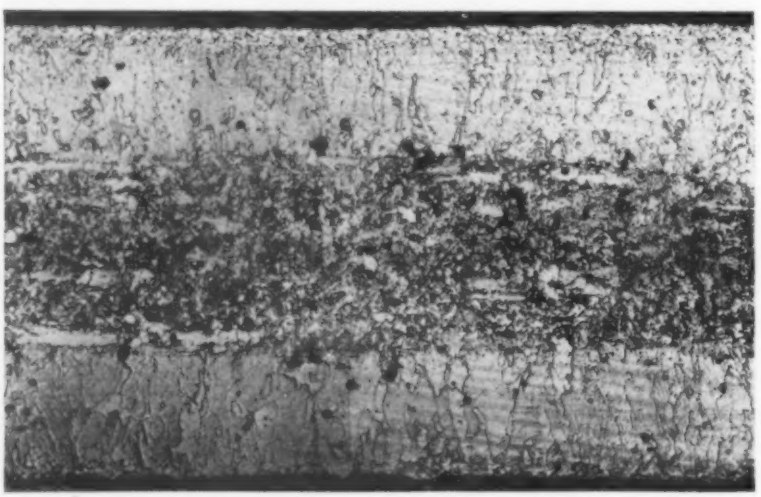
E = Excellent; G = Good; F = Fair; P = Poor; FS = Fair with special equipment; I = Impracticable

copper into the weld would destroy the main characteristics of the Nimoply, *i.e.*, its high thermal conductivity. Table III indicates the various combinations of metals that can be welded, and their relative merits.

Coated materials

It is frequently necessary to resistance weld assemblies in which some or all the surfaces of the components have been previously rust-proofed. The main trouble in such fabrication is that the coating tends to adhere to the electrode tips, causing them to stick to the metal. A production run necessitates frequent tip cleaning, and generally corrosion resistance is impaired in the vicinity of the spotwelds. In addition, the weld strength is erratic, and is usually lower than that for uncoated material. In spite of these problems, some production work has been carried out. Aluminized mild-steel sheet, consisting of low-carbon sheet coated on both sides with a thin layer of almost pure aluminium, has been successfully spotwelded (Fig. 21). For optimum tip life and weld strength consistency, the surfaces of the aluminized sheet should be cleaned before welding, and the coating should be about 0·001 in. thick. If it is thicker, poor welds result, and tip pick-up is caused. There is a tendency for copper pick-up to occur on the surfaces, and $FeAl_3$ (a brittle iron/aluminium compound) can be formed in the weld.

Cadmium-plated sheet shows a greater sensitivity to fluctuations in welding machine settings, and a greater tendency to electrode sticking, as compared with uncoated sheet. But welds of good quality can be obtained, provided that the electrode tips are frequently redressed, and that relatively high electrode pressures are used.



21—*Weld between aluminized mild steel sheets* ×20

Nickel and chromium plated materials are not so successfully spot-welded as other metallic coatings, principally because the coating is marred and partially destroyed, usually by cracking. The chromium or nickel content of the weld nugget may be high, and welding conditions generally are critical.

Sheradized, galvanized, and tin plated steels are said to be weldable, provided that the electrode tip size is carefully maintained.[7] Electrode sticking is not excessive, but the tips rapidly become fouled and frequent re-dressing is required.

Control of Quality

At the time this paper was prepared, it was impossible to impose any accurate control during the actual resistance welding operation. One aircraft manufacturer has installed electronic equipment on special welding machines; it indicates when a good weld has been obtained by recording any deviation from the mean welding current. The equipment cannot provide any remedial action if a bad weld is encountered. Another company is investigating the cycle of electrical resistance encountered for each weld. Indications are that, early in the welding cycle, an appreciable reduction in resistance occurs. If the reduction is delayed it is apparent that the weld nugget has insufficient time to form, and electronic equipment is suggested to rectify the current progressively throughout the weld run.

Until such time as this type of control has become established, production resistance welding is usually checked by the results of the examination of separately welded test pieces. Care is taken that these samples are welded in an identical manner to the production batch of components, and they are then passed to a weld test laboratory for examination.

The tests usually carried out to determine the weld quality of test samples are:

(*a*) *Visual Examination* to ensure that the surface appearance is satisfactory.

(*b*) *Tensile Shear Test*. Two overlapping sheets which have been resistance welded are loaded in tension, the weld itself being subjected to a shear load. This gives a good indication of the strength of the weld, but does not indicate its ductility or how the weld will behave under impact or fatigue.

(*c*) *Macro Test*. This form of examination is very simple, and is extremely useful in evaluating the quality of weld. Transverse or longitudinal sections through the weld are polished and etching discloses the structure of the weld with sufficient contrast for satisfactory examination at low magnification, usually ×15. Defects, weld diameter, penetration, and indentation can be measured with a scaled eye-piece.

(*d*) *Peel or Chipping Test*. The test piece is held in a vice and the sheets are prised apart, so that one sheet is peeled back over the other. A weld in which adhesion is poor, or where there is a large amount of cracking, will tear easily along the centre of the weld nugget.

(*e*) *Twist or Tension Test*. The test consists of twisting the two sheets apart about an axis perpendicular to the sheet and at the centre of the weld. Poor welds will shear free with a very small angle of twist. Good welds will shear after 90°–180° twist, depending somewhat on the inherent ductility of the material. This test is suggested as a shop test for those metals which peak harden on welding.[8]

(*f*) '*Pillow*' *Test*. The strength of a seamweld is seldom of prime importance, but leak tightness is a factor to be considered. The simplest form of pressure test is the 'pillow' test, in which two flat sheets are seam-welded around the periphery to form a closed container. A hole is drilled in one sheet and a connection is brazed or welded on the hole. Pressure testing then reveals whether the seamweld is sound.

Flash welding requires special testing requirements, and these include hardness testing, macro-etching, and tensile testing. Ultrasonic testing has been found to be more searching than radiological examination.

Projection welding necessitates periodic testing of actual parts, because of the infinite variety of shapes which can be involved.

Tests for resistance heated riveting usually take the form of specially prepared samples containing holes of the same size and countersinking as on the component.

Frequency of testing

The frequency of testing is of great importance, in view of the inability to inspect during actual resistance welding operations. Obviously, a test must be taken before a production weld run, to ensure that the correct welding technique has been employed. During the production of a batch of components, intermediate tests are also mandatory, and are carried out according to the length of the weld run, after electrode changes and any breakdowns that may occur. A final test is made on the completion of each welding batch, without any alteration in welding conditions or changing or dressing of electrodes.

The minimum testing requirements are specified in A.I.D. Inspection Instruction AS.4089/D.443, Issue 5, and the method of testing varies according to the type of welding process in use and the material involved.

Surface appearance

In the examination of a resistance weld test piece, the first consideration is the surface appearance. The weld should be free from surface cracks, tip pick-up, burning, or defects that would indicate that the welds have been made with dirty electrodes or material that has been improperly cleaned. The important points to look for, apart from surface conditon, are:

(i) Excessive indentation
(ii) Amount of overlap of parts joined
(iii) Position of the weld
(iv) Overlapping spots in stitch-welding and seam-welding should be spaced in accordance with drawing or standard requirements
(v) Excessive expulsion of metal.

Mechanical properties

The minimum tension shear test figures are usually the minimum design requirements and, obviously, vary according to the material and gauge combination. These requirements are based on results of numerous tests carried out under production conditions. Table IV gives the minimum loads for stainless and heat-resisting steels. Similar tables have been prepared for plain carbon steels, low-alloy steels, aluminium and its alloys, the Nimonic alloys, and titanium. Generally, the failure of the test piece should occur through the sheet, and not through the weld nugget.

Table IV

Tensile shear test requirements for stainless and heat-resisting steels

Sheet Thickness		*Electrode Tip dia. or Track Width,*	*Minimum Failing Load*	
			Spotweld,	*Seam and Stitch Welds,*
s.w.g.	*in.*	*in.*	*lb/spot*	*lb/in.*
28	0·0148	0·125	390	1055
26	0·018	0·125	485	1410
24	0·022	0·150	545	1720
22	0·028	0·150	870	2195
20	0·036	0·187	1225	2820
18	0·048	0·218	1545	3760
16	0·064	0·250	1855	5010
14	0·080	0·280	2190	6265
12	0·104	0·375	2510	7010

Peel and chipping tests provide a considerable amount of information. Peel tests are usually applicable to spot-welding and chipping tests are more suitable for seam and stitch-welding, and multi-thick spot-welding. The weld nugget should be torn from one sheet, and should not be less than 80% of the electrode diameter in size. The shape of the nugget is important, and must not be deformed in any way. Where no nugget is obtained this obviously indicates lack of fusion between the two parts.

Chipping tests on stitch and seam-welding will indicate blowholes, cracking, and any lack of penetration or fusion, as well as incorrect overlapping of welds.

Materials which are prone to peak hardening will prove brittle on testing, unless correctly post-heat-treated. For such alloys, the twist or tension test would be more suitable. Figure 22 shows diagramatically the general weld nugget and surface defects that can be expected.

Macro-examination

Macro-examination will reveal the depth of indentation caused by the electrodes and the amount of penetration of the weld into each sheet. The structure of the weld and heat-affected zone can be checked as well as the incidence of cracking, voids, blowholes, and the shape of the weld nugget. In seam and stitch-welding the overlapping of the welds is also checked (Fig. 23).

Indentation in resistance welding is usually indicative of excessive separation between the parts being joined, and also of undesirable operating conditions. Accordingly, welds with surface indentation of 10% or more of the total thickness welded are considered to be unsatisfactory. Indentation of irregular shape is indicative of a poor operating condition, and is unacceptable.

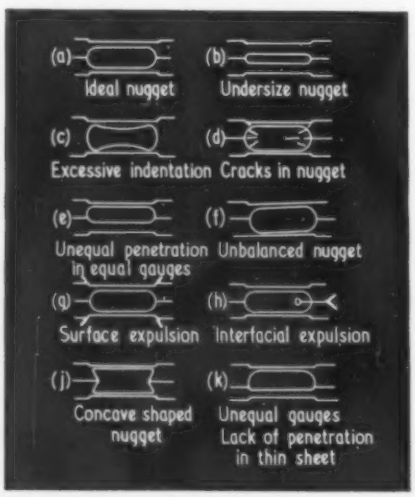
Weld penetration, expressed as a percentage of the combined thicknesses of the welded sheets, should be 40–80%, with a minimum of 20% in any one sheet. For materials with a greater thickness differential than 3:1 the minimum penetration is specified for each separate sheet. The same procedure is applicable to dissimilar materials.

There is definite evidence that severe cracks, *i.e.*, cracks extending beyond the weld metal proper, may produce a detrimental effect on the fatigue strength of the parts joined. Such cracks, therefore, are considered as defects. On the other hand, cracks contained within the weld metal, usually shrinkage cracks, are acceptable. Porosity is also not considered to have any detrimental effect on the general quality of welding, but cavities or large blowholes must occupy less than 25% of the total nugget volume, as estimated in the transverse direction. Longitudinal cracking is less frequent, but it is unacceptable, and so is lack of fusion.

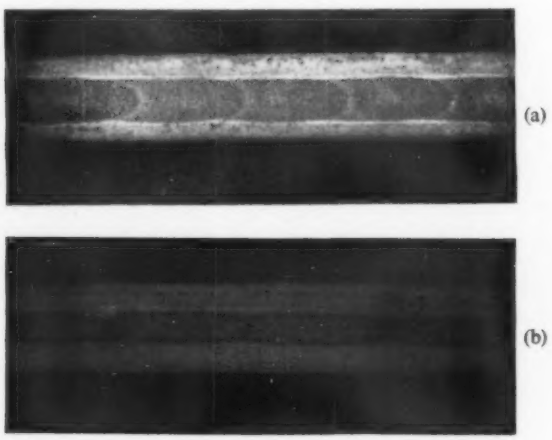
Macro-examination is carried out on hot riveting to ensure that the grain flow is symmetrical, and that the rivet head is not off-set. The stem must not be fused to sheet metal members, and the latter must not be distorted. The formed head must be free from cracks or signs of bursting at the circumference.

Butt welding faults

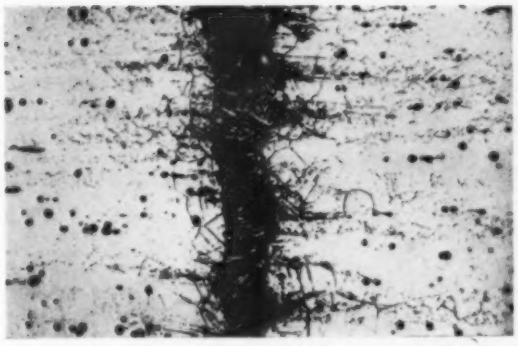
Butt, percussion, and flash welding require a different approach, but visual examination will disclose die



22—*Weld nugget and surface defects that may normally be expected in resistance welding*



23—*Macrostructures of seamwelds:* (a) *Good overlapping;* (b) *poor overlapping* ×10



24—*Dendritic material retained in Nimonic 90 flash weld* ×45

burns, cracking, and some indication of the weld quality. A steep slope in the upset area adjacent to the weld indicates that sufficient heat and pressure has been employed. Macro-examination and bend testing will reveal voids, oxides, lack of fusion, dendritic material, inclusions, and cracking (*see* Fig. 24). Tensile tests are frequently made to obtain unit mechanical properties. Magnetic materials, of course, can be checked by magnetic particle detection methods for surface defects, but radiography does not appear to be suitable, because it is difficult to disclose faults other than large voids. Ultrasonic testing by the shear-wave technique seems to be particularly useful, and has been adopted for high-class weldments on stainless steel, Nimonic alloys, and titanium.

Final inspection

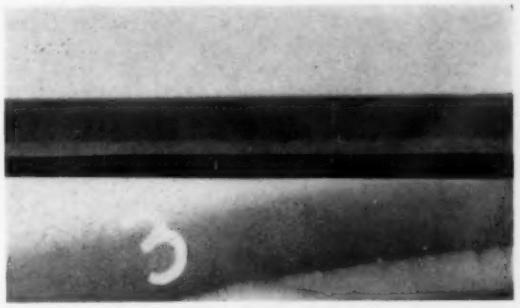
The inspection of finished resistance welded units is carried out by visual examination, dye penetrant checks, and possibly by radiological tests on non-magnetic materials. Radiography is useful, as Fig. 25 shows, by indicating porosity and cracking. Magnetic particle detection is an additional test on units composed of magnetic materials. Where special properties, such as ability to hold internal pressure, are required, a suitable pressure test is evolved. Sometimes the dye penetrant check is used to check leak-free resistance welding, as shown in Fig. 26.

Conclusions

From the practical aspects of the process described in this paper it will be realised that great strides have been made in the development of specialized equipment for resistance welding, and in the general improvement of machine construction. Considerable progress has been made in the control of weld quality, and further research is being conducted to ensure the production of high-quality welds.

Acknowledgments

The authors wish to acknowledge the courtesy of their employers, Bristol Siddeley-Engines Ltd., for permission to publish technical details and illustrations. Thanks are also given to colleagues of the organization for their assistance in preparing the paper.



25—*Radiograph showing porosity and cracking*

26—*Applying a dye penetrant to check leak-proofness of seam-welded jet pipe*

REFERENCES

1. Philips Resistance Welding Handbook, 1stE dition, pp. 123–125. Philips Industrial Ltd.
2. W. F. Hess, W. D. Doty, and W. J. Childs: *Welding J.*, 1947, vol. 26, pp. 641s–652s.
3. O. H. Henry and G. E. Clausen: "Welding Metallurgy", 2nd Edition, 1949, pp. 426–444. American Welding Society.
4. "Resistance welding of nickel and nickel alloys". Technical Bulletin T.33, 1952, pp. 14–15. International Nickel Co. Inc.
5. A. D. McQuillan and M. K. Mcquillan: "Titanium", 1st Edition, 1956, pp. 120–121. Butterworth Scientific Publications.
6. Technical Paper, June 1958 (Finlay, Vordabe, and Mahone). Crucible Steel Co.
7. A. J. Hipperson: *Sheet Metal Ind.*, 1954, vol. 31, pp. 214–217.
8. E. J. French and A. A. Wells: *Brit. Welding J.*, 1957, vol. 4, pp. 514–529.

Automatic Vertical Welding

By J. A. Lucey B.A.(CANTAB) *and D. D. Smout*

The paper describes briefly the development of the Russian electro-slag process from submerged-arc welding, and then illustrates the basic principles of the process.

It is shown that the design of equipment plays an important part in the successful application of the process, and several examples are illustrated to explain methods of attaining and controlling the vertical traverse, the design of the copper dams, and the means of providing a satisfactory flow of powder.

The effect of the welding variables on the functioning of the equipment is considered, and information is given on the properties and quality of the welds it produces.

The paper is concluded with an indication of some of the most advantageous applications of the process, and with a comparison of its economics with that of the conventional submerged-arc process.

Introduction

In a paper which is concerned with the development of an automatic process for welding vertical seams, it is pertinent to review some of the steps which have led to the present achievements.

One of the first to envisage the use of mechanical support for the weld metal when making a vertical weld was Rockefeller.[1] In 1933 he described a machine for welding vertical seams, incorporating damming blocks pressed against both sides of the joint with means for raising these blocks together with the welding torch or torches as welding progressed up the seam.

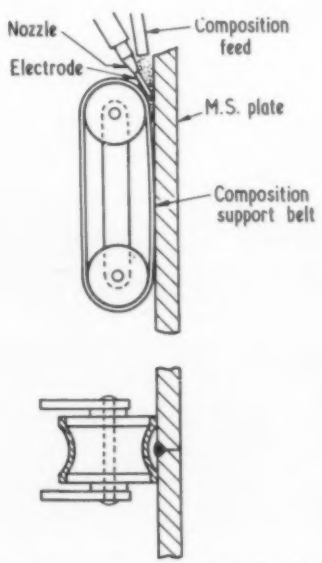
Other investigators who have specifically aimed at the development of the submerged-arc process for vertical welding have had a different approach by using the welding composition itself as the means for supporting the molten weld pool. The principle of using an endless belt to keep the composition pressed against the weld seam, as shown in Fig. 1, has been described by Meyer[2] and others.

The principal problems involved with these methods are maintaining uniformity of finish and obtaining welds free from slag inclusions by the natural tendency for molten slag to float to the top of the weld pool.

With these systems there is generally no means of varying the vertical rate of travel, so that variations in preparation or any tendency for weld metal to fall under the influence of gravity will lead to lack of uniformity and unsatisfactory welds.

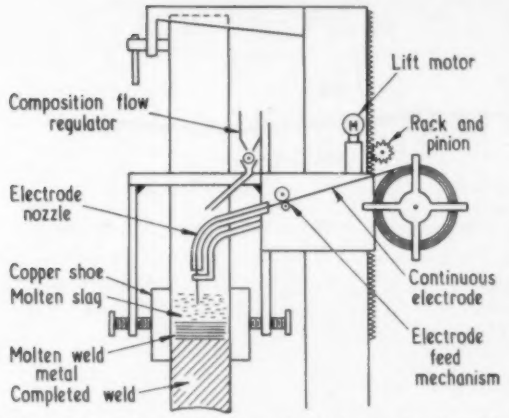
The development of vertical welding, using copper dams to maintain the metal in position, stems from the use of water-cooled copper moulds for making heavy submerged-arc welds, such as those used extensively in the manufacture of heavy chain cable. The bottom of the weld was generally supported by the stud in the centre of the link but the sides of the weld were formed by the copper mould.

This application of submerged-arc welding was the forerunner of the method of vertical welding pioneered in the U.S.S.R., which has been termed the 'electro-slag process'. With this process the arc is initiated on



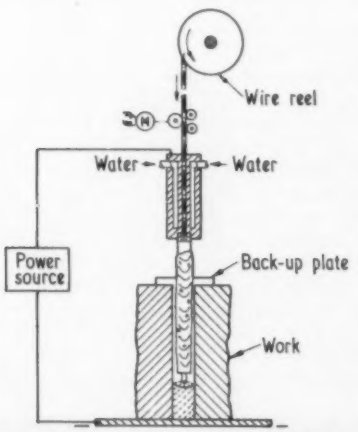
1—*Vertical submerged-arc welding with endless belt support*

Paper to be presented at a special meeting on 1st October 1959.
Manuscript received 6th August 1959.
The authors are with Quasi-Arc Limited, Gateshead.

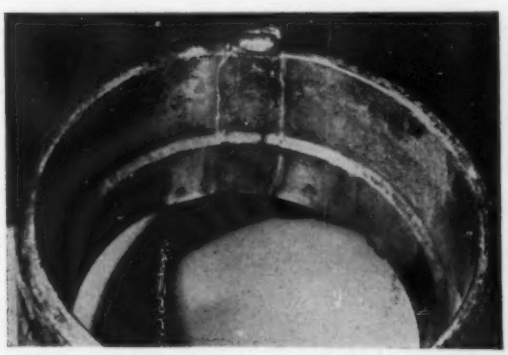


2—*Principle of electro-slag or vertical submerged-melt welding*

some form of run-on plate and thereafter the current passes from the tip of the electrode to the surface of the molten weld pool through molten slag. The pool itself is contained between the faces of the joint by damming blocks, which are traversed vertically up the joint together with the wire feeder as metal is deposited (Fig. 2).



3—*Vertical welding with a consumable guide tube*



4—*Submerged-melt weld in a ring section made by traversing the welding head vertically at a preset speed*

The great advantage of this method of vertical welding, compared with other methods of vertical submerged-arc welding, is that the electrode is perpendicular to the surface of the deposited metal as it rises in the joint so that variations in joint fit-up do not present any problem of providing sufficient metal to fill the joint. At the same time the design of joint always ensures that full penetration through the whole width is achieved.

Since this process became established an alternative method of welding has been proposed which involves the use of a consumable electrode guide tube in addition to a consumable wire electrode. The tube may be coated with a slag-forming material and is of a length to suit the joint to be welded. The weld metal is contained between the joint faces, and copper bars running the full length of the joint are clamped to it. When the arc is struck, metal is continuously deposited from both the guide tube and the electrode wire, which is fed through its centre (Fig. 3). This principle is of particular value if the plate thickness varies up the joint so that it is impractical to use sliding dams.

It is, however, possible to use an extended non-consumable electrode guide and to move the welding head vertically as the weld metal progresses up the joint. This is how the ring shown in Fig. 4 was welded, the rate of travel being pre-set after calculation of the time required to complete the weld.

Basic Principles of Electro-Slag or Vertical Submerged-melt Welding

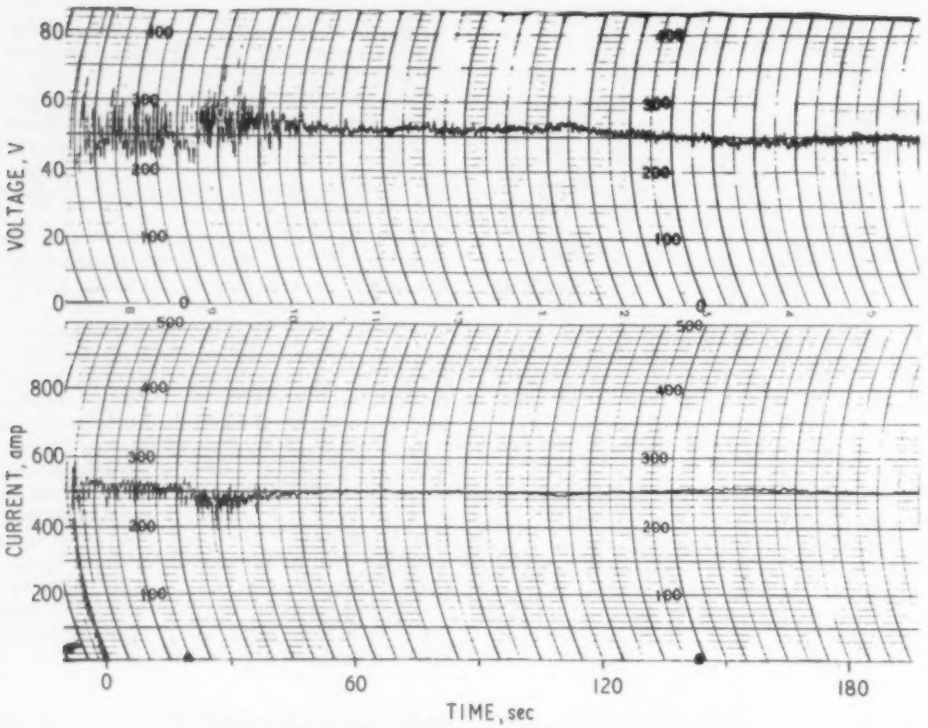
The "Arc"

Whilst it has been shown that electro-slag welding may be regarded simply as one of the possible methods of vertical submerged-arc welding, there is, nevertheless some justification for omitting the word 'arc' in describing it.

In normal submerged-arc welding the passage of current from the electrode tip to the workpiece is, at least partially, in the form of an arc. This may be demonstrated by reducing the burden of welding composition so that it only just covers the tip of the electrode. The top portion of the arc is then clearly visible through the layer of powder.

There is no true arc in electro-slag or vertical submerged melt welding other than at the opening phase. At the start of a weld an arc is struck at the bottom end of the vertically mounted preparation under a quantity of welding composition. During this stage the process is characterized by fluctuations of current and voltage (Fig. 5), by a harsh crackling, and by agitation of the powder composition. This continues for the first 20–30 sec, while the composition is being converted to a bath of highly fluid slag with a temperature that rises above that of molten steel. As soon as this bath has been formed, fluctuations in voltage and current cease almost entirely (Fig. 5), the harsh crackling stops, and the top surface of the slag bath is observed as being only slightly agitated and white hot. It is at this point in the opening cycle of a vertical weld that the arc is extinguished.

The transfer of current from the top of the electrode to the surface of deposited metal takes place entirely across the liquid slag, there being no hot ionized gas as in a true arc. Thus, despite the turbulence of the molten



5—Voltage and current recordings of a vertical submerged-melt weld

slag, there is no noticeable bubbling of gas at the surface. Confirmation of this change has been provided by Benua and Katler,[3] who used oscillograms showing the change from the distorted wave form associated with an a.c. arc to a pure sine wave form when the slag bath had been formed. Muller[4] also showed that a radiograph taken during welding revealed no bright space between the electrode tip and the surface of the weld metal, indicating that there was no gas present.

This radiograph also makes it clear that the resistance of the molten slag to the passage of current is of the same order as that across an arc. This would be expected, for the 'arc' voltage in electro-slag welding for best results is of the same order as that which would be used for normal submerged-arc welding under similar conditions of current and electrode extension.

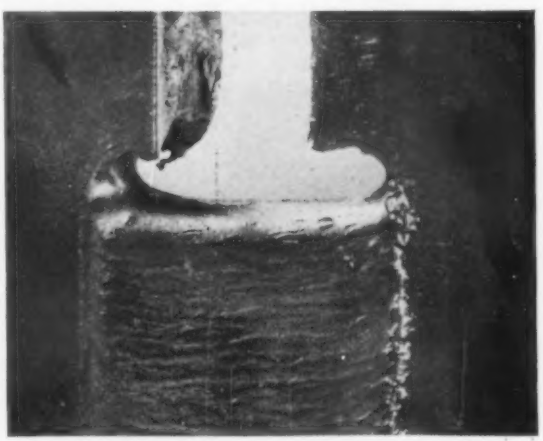
Stability

To maintain stable welding conditions it is essential that the rate of vertical movement of the copper dams and the electrode feed mechanism should be in strict relation to the rising level of molten weld metal. If the movement is too slow in relation to the metal deposit rate, the weld metal level will rise towards the top of the copper shoe and will force the slag bath to overflow. If the movement is too fast, the metal level will approach the bottom of the shoe with consequent loss of both fluid metal and slag.

It is, in fact, important to maintain a constant distance between the tip of the electrode nozzle and the weld metal surface owing to the change in wire burn-off rate with change in the length of electrode extension or protrusion from the welding nozzle. Such changes lead to a disturbance of the heat-flow pattern and so to variations in the finished weld (see p. 402).

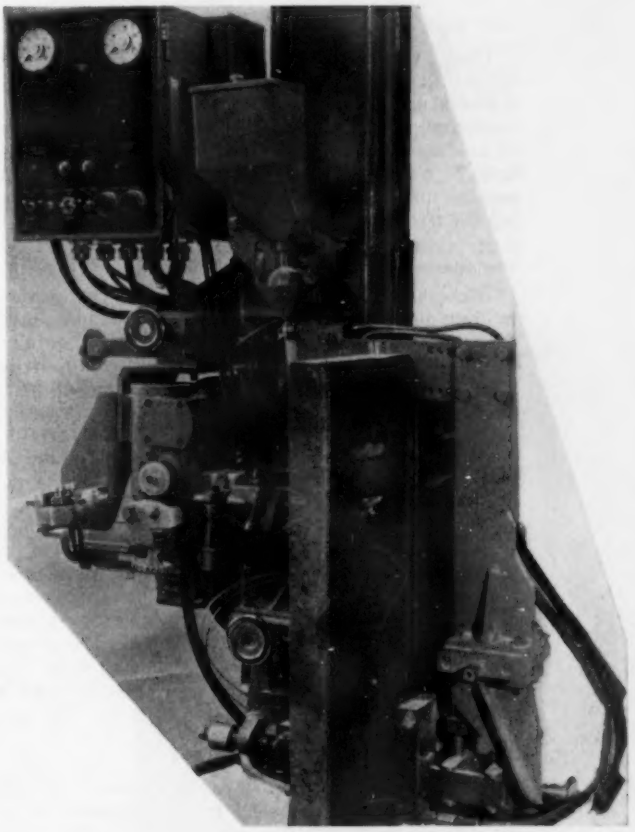
Another factor which has an important influence on the stability of the process is the depth of the slag bath. If this is allowed to become too shallow (less than about $1\frac{1}{2}$ in.) it may reach boiling point or an arc may develop between the electrode tip and the slag surface.

The gap between the two faces of the joint also has an appreciable influence on stability, for if it is decreased below $\frac{3}{4}$ in. there may be instability, probably because of a tendency for the current to flow from

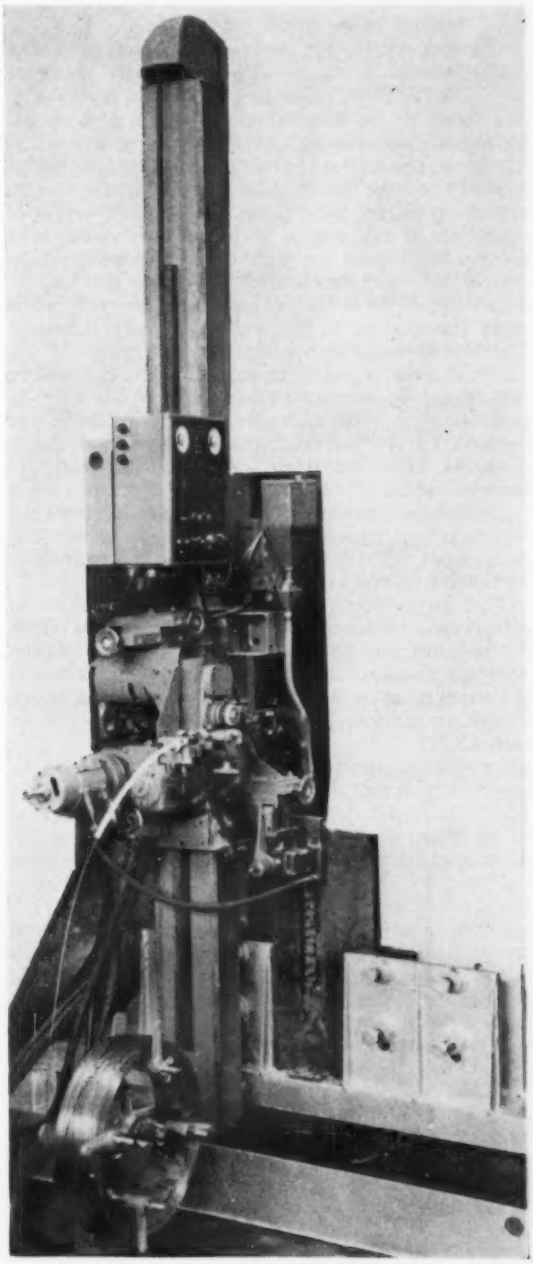


6—Partially completed vertical submerged-melt weld

8—*Close-up view of the traversing carriage of the machine showing the wire feed unit, adjustments, and mounting arrangements for the copper dams*
(Right)



(Below)
7—*Specially developed machine for vertical submerged-melt welding*



the electrode wire to the side faces of the joint rather than from the tip of the electrode to the surface of the deposited metal.

Welding composition which is added at too fast a rate will affect the temperature of the slag bath and will lead to a disturbance of the welding conditions.

Penetration

In electro-slag welding the term 'penetration' refers to the depth of fusion into the side walls of the joint. This penetration is effected not by hot deposited metal, but largely by melting of the plate by slag which has been heated well above the temperature of molten metal. This is clearly shown by the appearance of a weld which has been only partially completed (Fig. 6). The edges of the joint immediately above the weld metal surface have been melted away almost to the full width of the weld penetration. At the start of a weld, where time is needed to melt the slag and raise it to a sufficiently high temperature, full penetration is not normally obtained.

Where the ratio of plate thickness to gap width is much more than $2\frac{1}{2}:1$, uniformity of penetration across the full width of the joint cannot be obtained by using a single electrode wire. Thus for plates over $2\frac{1}{2}$ in. thick it is customary to weave the electrode back and forth across the width of the joint or to use two or more electrode wires.

Equipment

Design of equipment plays an important part in the successful application of vertical welding. Some features are common to all submerged-arc welding machines, but several are peculiar to this new method of welding. Some of the more important aspects which have been studied are outlined in the following section, and the machine which was designed and built following these studies is illustrated in Figs. 7 and 8.

Vertical traverse

The general principle adopted for most vertical welding machines has been to mount the welding head on a carriage designed to traverse a vertical column acting as a track. With this system the track must be aligned with the joint before welding and securely clamped so that there is no risk of relative movement between the track and the job during welding.

To avoid the need to transport the vertical column from one job to another, one of the machines developed in Russia relies on an electro-magnet to hold it to the job; it also incorporates a mechanism which enables the machine to 'walk' up the workpiece. Whilst this equipment has a definite advantage in portability, it relies entirely on electric power to retain itself in position, and any power failure would not only damage the machine, but would endanger the operator owing to the spilling of molten metal and slag. This hazard would probably rule out the use of such a machine in the U.K.

Control of vertical traverse

A control system for regulating the speed of vertical lift as the weld progresses is a most important feature of any machine intended for anything other than laboratory tests on vertical welding. It has already been made clear that uniform results are possible only when the copper dams and electrode nozzle are maintained at a uniform height in relation to the surface level of molten metal as it rises in the joint. In a laboratory set-up, where the joint gap can be accurately measured and the amount of metal required to fill the joint can be calculated, a vertical control system may not be essential. But a machine that must be able to cope with a variety of work and the variations in fit-up that are liable to be encountered in production must be equipped with an automatic device for height regulation.

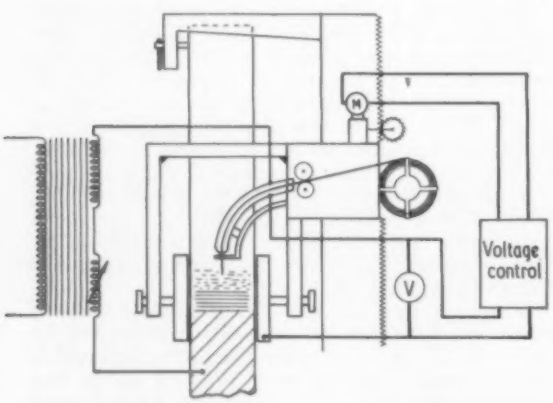
Three possible systems have been investigated by the authors:

(i) A direct system using a voltage measured between the electrode nozzle and the work as the indicating signal
(ii) A probe, mounted in the side of one of the copper dams, and which expands or contracts depending on its proximity to the hottest part of the weld zone
(iii) A differential system for detecting the hottest area in the vicinity of the weld metal surface.

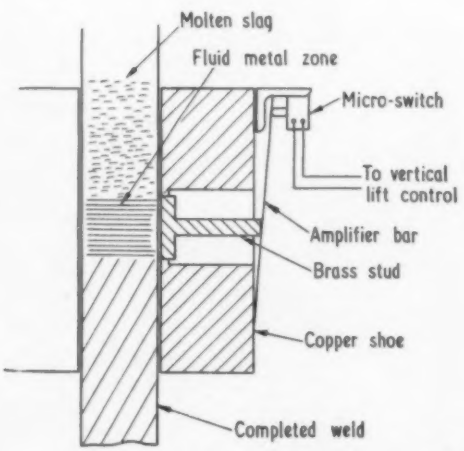
The first system (Fig. 9) has the advantage of simplicity and of being independent of any probe or special connections made to a sliding copper shoe. It can therefore be used to make welds in a mould formed with fixed copper blocks, where it may not be feasible to use any of the other control systems which depend upon the use of at least one copper dam that moves up as the weld progresses. The principle of operation of this system is based on the use of a governed wire-feed speed and a comparatively high current density in the electrode wire. As is well known, an arc exhibits a self-adjusting characteristic which is more pronounced as the current density increases. This also applies with the electro-slag process.

The manner in which the control works can best be understood by consideration of the electrode burn-off characteristics. With high current densities the rate of burn-off is greatly influenced by the length of electrode extension. This is due to electrical resistance heating in the wire, which is proportional to I^2RT, where I is the current, R the resistance of the wire, and T the time the wire takes to traverse the length of the extension. Apart from this effect the burn-off rate is directly proportional to current for any given wire size.

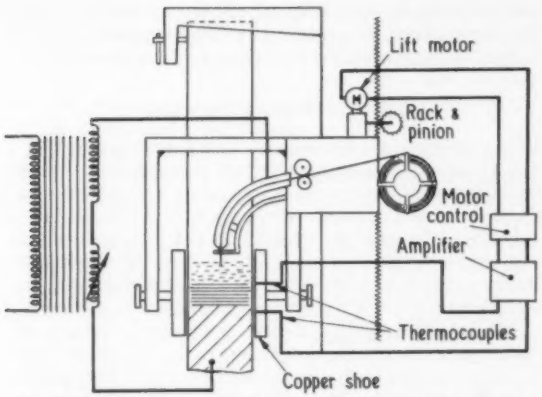
Thus any tendency for the electrode extension to increase will reduce the welding current so as to match the burn-off rate to the wire feed speed. With any drooping characteristic power source a reduced output of current must be matched by a rise in voltage, which is used as an indication for reducing the speed of vertical lift.



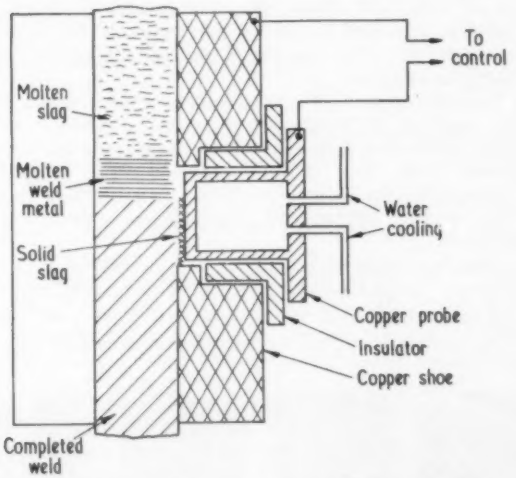
9—*Schematic diagram of a voltage control system for vertical lift regulation*



10—*Expanding stud system for vertical controlled lift*



11—*Differential thermocouple system for the control of vertical lift*



12—*Water-cooled copper probe system of vertical lift control*

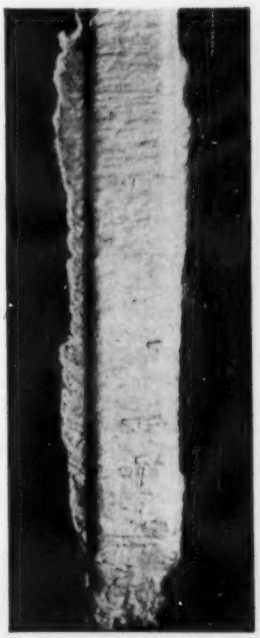
The second system (Fig. 10) which relies on the expansion or contraction of a stud set in the copper shoe, has proved to be effective and simple to set up. But it can easily be put out of adjustment or be influenced by the rate of flow of cooling water in the copper dam.

The third system (Fig. 11) overcomes these drawbacks. By using the face of the copper dam as one conductor of each thermocouple there are no problems of ensuring good heat conduction from the weld zone to the thermocouples and the set-up is quite robust. A transistorized amplifier makes the control very sensitive and it has proved to be reliable and satisfactory for a wide range of welds.

Other systems have been used in Russia and elsewhere for controlling the vertical lift. One of these (Fig. 12) makes use of a water-cooled probe set within one of the copper dams but insulated from it. In some positions relative to the weld zone, current can pass from the probe through liquid slag or metal, but at others a layer of slag adhering to the probe interrupts the current path. The disadvantage of this system is that, when using a wide weave, a layer of slag may solidify on the water-cooled probe when the electrode is furthest away from it. Similar problems may arise on starting or when there is a change in the flow rate or temperature of the cooling water.

Copper dams

An important factor in the performance of a successful vertical weld lies in properly designed copper dams. They must be of sufficient length to support the slag bath and the fluid weld metal until solidification occurs. The dams must be adequately cooled and must be capable of following irregularities



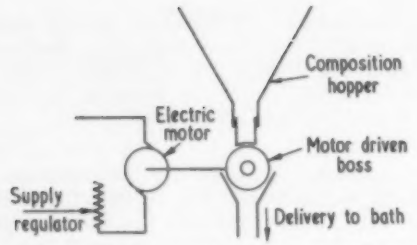
13—*Vertical weld made with a dam having too narrow a groove. This weld also shows the effect of varying penetration*

in joint fit-up. They must have a machined groove of suitable width and depth to allow for a thin skin of solidified slag to form on the face of the weld without producing undercut or other irregularities in the finished weld.

Figure 13 shows a deposit made with a dam having a groove too narrow and too deep. Slag trapped between the plate and dam surfaces adjacent to the reinforcement zone has produced depressions or undercut up to $\frac{1}{16}$ in. below the plate surface. Another deposit made with a dam having a shallower and broader groove, producing a deposit without undercut, is shown in Fig. 6.

Specially shaped dams may be needed for specific applications; for instance, on welds in cylinders or corner joints, or where plates of dissimilar thickness have to be welded together.

The dams must be mounted on the machine so that they can always be forced tight against both sides of the joint. A force of about 100 lb is needed to prevent any tendency for weld metal and slag to force the shoes out of contact with the plates being welded.



14—*Principle of the flow regulator for metering the flow of welding composition*

Powder flow

During the making of a vertical weld a skin of slag approximately $\frac{1}{32}$ in. thick forms between the faces of the dams and the deposited metal surfaces. This protective covering is derived from the slag bath. To make good this slag loss and to maintain a constant depth of slag bath, welding composition must be added to the bath while welding. Since it was found that a momentary large addition of powder composition to the top free surface of the bath can produce short periods of bath instability, a metered melt flow system was found to be desirable.

The system found to be most satisfactory consists of two hoppers, a large upper store hopper, separated from the small lower delivery hopper by a power-driven wheel (Fig. 14). The gap between the delivery tube from the upper hopper and the wheel surface is adjustable, and the rotational speed of the wheel is under the direct control of the operator.

At the commencement of the weld, a relatively large supply of composition is required during the bath-forming stage. This is obtained by setting the wheel at its maximum rotational speed. Once the bath is formed, it is maintained by adjusting the wheel speed to give a very slow trickle feed sufficient to replace the loss.

Effect of Welding Variables

In conventional downhand submerged-arc welding the effects of changing current, voltage, and travel speed are well known, An increase in current gives an increase in penetration, whilst an increase in arc volts actually decreases penetration and produces a wider and flatter reinforcement. Greater traverse speed produces a narrower weld with less reinforcement and, at speeds below 12 in./min, slightly greater penetration.

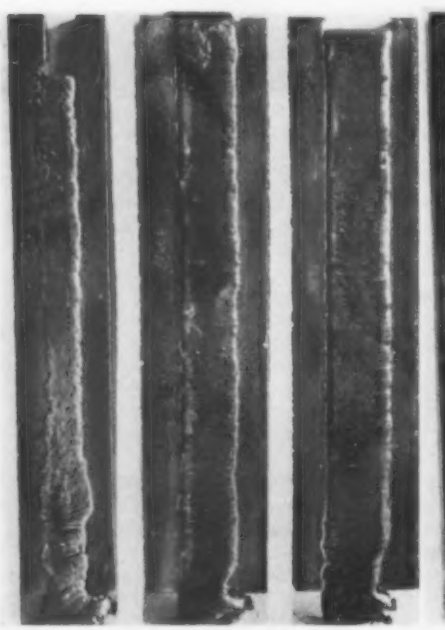
In vertical submerged-melt welding the effects of these variables are quite different. Arc voltage and not welding current is the principal factor affecting penetration, and neither have any effect on reinforcement, which is controlled by the shape of the copper dams.

Traverse speed is no longer an independent variable, since it is entirely dependent on the rate at which weld metal is deposited to fill the gap between the plates being welded. This variable is replaced by another—electrode extension.

The influence of the electrical resistance heating of the length of electrode protruding from the nozzle on electrode burn-off rate has been mentioned in connection with one form of control system for the vertical lift. An indication of the magnitude of this effect is best appreciated by studying a particular example:

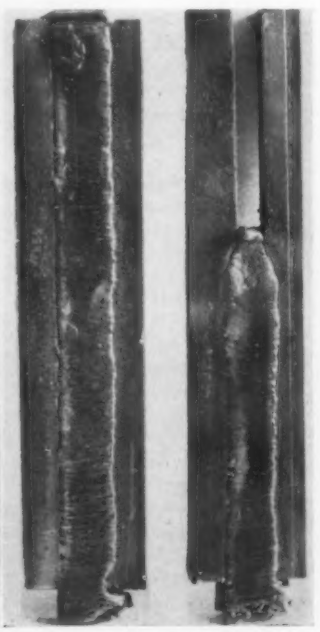
Wire dia., in.,	*Welding current, amp.*	*Electrode extension, in.*	*Burn-off rate, lb/hr.*
$\frac{3}{32}$	500	1	15
$\frac{3}{32}$	500	$3\frac{1}{4}$	30

An increase in electrode extension produces two



15—*Effect of voltage:* (a) *45 V;* (b) *50 V;* (c) *55 V*

16—*Effect of welding current:* (d) *400 amp;* (e) *500 amp;* (f) *600 amp*



17—*Effect of electrode extension:* (g) $4\frac{1}{8}$ *in.*; (h) $5\frac{5}{8}$ *in.*

major effects on a vertical weld. Firstly, it increases the deposit rate and hence the traverse speed. Secondly, it reduces the proportion of electrical power available for melting the parent plate, and the duration of time that the hot slag is in contact with the plate edges. As a result, penetration is reduced.

To clarify the effects of the various welding parameters the following illustrations and tables are given. These were compiled from welds made in 1 in. thick plate with a 1 in. gap.

Effect of voltage (see Fig. 15)

	Weld No.	*Voltage V*	*Current amp*	*Wire Extn. in.*	*Wire Feed Speed in./min*	*Average Traverse Speed in./min*	*Average Width of Weld in.*
(*a*)	VW70	45	500	4½	285	1·8	1¼
(*b*)	VW69	50	500	4½	240	1·5	1 13/16
(*c*)	VW71	55	500	4½	235	1·5	2¼

Effect of current (see Fig. 16)

(*d*)	VW72	50	430	4½	180	1·2	1⅜
(*e*)	VW69	50	500	4½	240	1·5	1 13/16
(*f*)	VW73	50	600	4½	360	2·1	1 15/16

Effect of electrode extension (see Fig. 17)

(*g*)	VW69	50	500	4½	240	1·5	1 13/16
(*h*)	VW74*	50	500	5⅜	335	1·9	1¾

** With this extension arc initiation was unreliable, wire straightening and positioning was erratic, weld failed when wire arced to one side of the preparation.*

Distortion and Shrinkage

One of the features of butt welds made by vertical submerged-melt welding is the complete lack of angular distortion. This is inherent in the fact that the weld is made in a single run with the same face width on each side of the joint. Since, with other methods of welding, distortion often presents major problems on heavy plate, this characteristic is of considerable importance.

Although there is no angular distortion, transverse shrinkage occurs as with other fusion welding processes. Measurements of transverse shrinkage were made with the dual object of assessing the need for restraining bars to maintain a constant gap distance and to gain some indication of the extent to which restraint might be expected to influence any tendency towards cracking.

Over the range of welding speeds, from 6 in./min upwards, used with normal downhand submerged-arc welding, some measure of restraint to prevent the joint opening up as welding progresses is essential to prevent cracking. Such restraint is most usually supplied by tack welding.

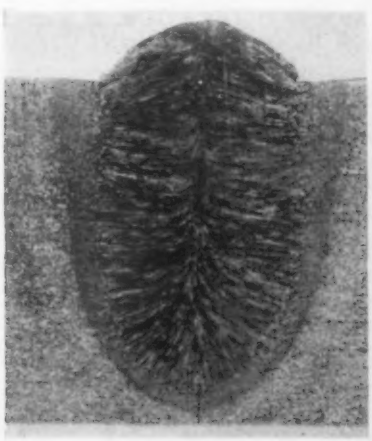
With vertical submerged-melt welding, however, welding speeds are generally less than 2 in./min, and measurements made on unrestrained butt joints have shown that except at the start of the weld, when some initial expansion occurs, the joint faces are tending to close in a little as welding progresses. On 1 in. thick plates spaced 1 in. apart and welded at a speed of 1¼ in./min, measurements were made at a point 3 ft from the start of the weld using a dial indicator having a scale graduated at 0·0005 in. intervals. After completing 5 in. of welding, the gap had opened by 0·15 in. but at the end of the weld the gap width had contracted to 0·92 in.—an overall shrinkage of 0·08 in. Shrinkage of this magnitude is not unexpected with a weld width of 2 in.

Weld Quality

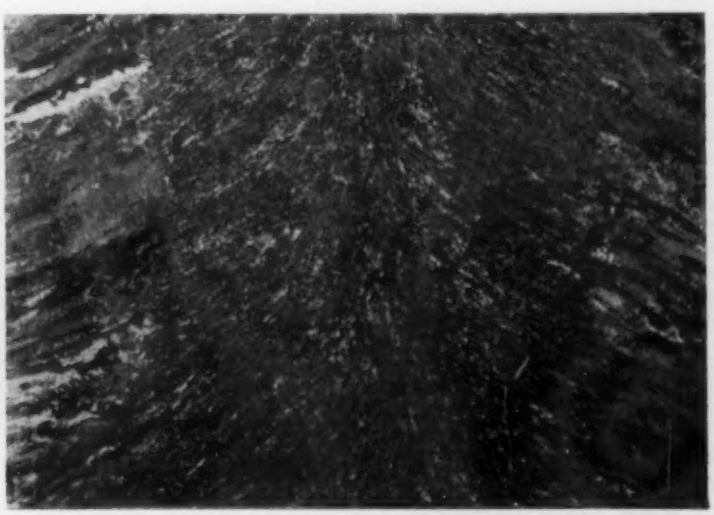
X-ray soundness

Numerous radiographs and sections of test welds made under varying conditions have shown that vertical submerged-melt welds are remarkably free from normal weld defects, such as slag inclusions and porosity. Only in one instance, when making trials with a wire containing insufficient deoxidants, have such defects been revealed; some piping occurred originating from the edge of the fusion zone.

Freedom from defects of this nature is a natural consequence of having a pool of weld metal which remains molten much longer than with conventional



18—*Heavy downhand submerged-arc weld with a crack originating in the plane where the dendrites solidifying from the vertical sides of the fusion zone meet in the centre of the weld*



19—*Macrograph of longitudinal section of vertical submerged-melt weld*

downhand welds. This allows time for gases generated from rust or scale on the plate edges to escape before the metal freezes.

All welds made have been free of cracks, whether the joints were restrained or unrestrained. It had originally been anticipated that cracking might occur under restrained conditions owing to the natural form of solidification of the weld metal in dendritic crystals originating from the parallel edges of the fusion zone and from the water-cooled copper shoes. Experience with heavy downhand submerged-arc welds has shown that where the fusion zone is almost parallel sided, the dendrites forming from each side meet in the centre of the weld, resulting in a plane of weakness which may easily result in the formation of a crack (Fig. 18).

In the vertical welding process, however, there is always molten metal above that which is solidifying, so that the dendrites tend to curl upwards and so avoid forming a sharp cleavage plane. This is illustrated in the vertical macro-section shown in Fig. 19.

Physical properties

Previous experience with heavy single-pass submerged-arc welds has shown that a coarse columnar grain structure does not have any definite influence on the tensile strength and ductility of the weld metal. It is not very surprising, therefore, that vertical submerged-melt welds made with the same consumables as are commonly used for multi-pass submerged-arc welds should have similar physical properties, with the exception of notch ductility as measured by impact tests. Some actual data are as follows, for vertical submerged-melt welds in 1–2 in. thick boiler quality mild steel plate, using $\frac{3}{32}$ in. dia. Wire *A* at 400/500 amp, and 45/50 V alternating current:

Condition	*Dia. of specimen, in.*	*Yield Stress, tons/sq.in.*	*Ult. Stress, tons/sq.in.*	*Elong. (3·54√A), %*	*Red. in Area, %*
As welded	0·424	24·3	34·4	30	60·7
Stress relieved at 650°C.	0·424	22·2	32·3	34·7	65·5

Notch ductility

Numerous Charpy impact tests, with the notch in various positions in the weld, have shown that there is a general, though not universal, tendency for results to be a little lower when the notch is machined near the centre of the weld. The figures given in Table I include those taken near the face and the centre. It is clear that, as expected, the large columnar grain structure results in values generally lower than those obtained with normal submerged-arc welds, but it must be emphasized that the wires *A*, *B*, *C*, and *D* used in this series of experiments were not specifically adapted to the requirements of the process, but were chosen for their different compositions, which varied in general deoxidation level and deoxidizers. The results show that small but significant differences in impact are brought about by changes in wire composition.

Table I

Notch-ductility of vertical submerged-melt welds

Ref.	*Wire Condition*	*Charpy V-notch values, ft/lb At Room Temperature* Min.	Max.	Average	*At —10°C.* Min.	Max.	Average
A	As welded	11·6	17·4	14·6	5·8	14·1	10·4
	Stress relieved	16·6	23·1	22·7	5·8	15·9	9·7
	Normalized 915°C.	52·1	56·4	53·4	28·9	34·0	32·0
B	As welded	28·2	29·6	29·0	13·7	18·8	
	Stress relieved	24·6	34·7	28·9	11·2	21·0	
C	As welded	19·8	36·9	28·4	8·0	9·4	8·7
	Stress relieved	24·6	26·8	25·7	7·2	8·7	8·0
D	As welded	10·8	19·5	15·2	3·6	3·6	3·6
	Stress relieved	14·5	22·4	18·5			

Stress relief has little or no effect, but normalizing at 915°C., which effectively refines the grain structure, has a most marked influence. Not only is the general level of results brought into line with that expected from multi-pass submerged-arc welds, but the scatter in results is also reduced.

Hardness surveys

The results of a hardness survey (Fig. 20) on a weld made with Wire *A* show reasonable uniformity over the main body of the weld with no hard zones.

Chemical composition of weld metal

Analysis of the weld metal at various levels in a single weld has shown very little change in chemical composition, although the Mn content at the start is generally a little lower than in the remainder of the weld, as can be seen from the following figures:

	C, %	Mn, %	Si, %	S, %	P, %
Start of weld	0·17	0·94	0·09	0·027	0·031
Finish of weld	0·17	1·23	0·07	0·025	0·033

It must be realized that the plate composition itself has an important bearing on the weld metal analysis as it may supply up to 50% of the weld metal. Such a proportion is typical of most automatic welds.

Applications

It is important to realize that vertical submerged-melt welding is not just a method of automatic welding of seams which cannot readily be positioned for downhand welding. It is a process that offers remarkable advantages in speed and economy for welding heavy plate thicknesses. With a lower limit of plate thicknesses of $\frac{3}{4}$ in., the process shows to best advantage on plate over 2 in. thick. On such heavy plate it is faster and more economical than the fastest downhand

20—*Position of hardness tests on a vertical submerged-melt weld using electrode* A. *(Open figures at start, those in parentheses at finish).*

multi-pass welding techniques, as is shown by the following comparison:

Butt weld in 2 in. thick plate

	Arc Time per foot of Weld, min	*Total Weight of Consumables per foot of Weld, lb*	*Welding Current, amp*
Two electrode, multi-power submerged-arc, multi-pass	12·8	10·3	450–1600
Single electrode vertical submerged-melt	8·4	8·5	650

There are also other factors which favour the vertical welding process, such as:

(1) Square plate edges eliminating the need for costly machined **U** preparations
(2) No deslagging
(3) No back gouging
(4) Minimum reinforcement requiring virtually no grinding
(5) Reduced plate manipulation—no turning over
(6) Continuity of operation
(7) No angular distortion.

It is clear, therefore, that this method of welding may well replace other welding processes on many applications involving heavy plate fabrication. With suitable equipment and by using copper dams it is possible to make circumferential welds, heavy fillet and **T** butt welds and butt welds with permanent steel backing.

In the U.S.S.R., electro-slag welding has been used for the fabrication of frames for heavy presses, guillotines, and forging hammers, for pressure vessels and in bridge construction, for heavy circular sections such as propeller shafts, connecting rods, and turbine shafts and even for some special hardfacing applications. In particular, it has been used to reduce the size and complexity of some castings and forgings, for it makes feasible the welding together of two smaller forgings or castings to forgings.

In Britain serious consideration has already been given to the use of this process for hydro-electric plant construction, for welding cylinders such as motor yokes, for welding heavy flange plates of long girders and even for the production of larger plates from a steel mill.

This new process undoubtedly offers scope for new and original thinking on the possible economies that welded fabrication may now be able to achieve compared with well established methods of welding, forging, and casting.

Acknowledgments

The authors wish to thank Quasi-Arc Limited for permission to publish this account of work carried out in their Research Laboratories.

REFERENCES

1. H. E. ROCKEFELLER: U.S. Patent, 2,089,840: 1937.
2. H. M. MEYER *et al.*: U.S. Patent 2,638,524: 1953.
3. F. F. BENUA and A. I. KATLER: *Avto. Delo.*, 1953, vol. 24. No. 5, pp.17-19.
4. R. MULLER: *Schweiss. u. Schneid.*, 1958, vol. 10, pp. 359–367.

NON-DESTRUCTIVE TESTING

Book Review

J. F. HINSLEY, "*Non-Destructive Testing*": London, 1959, Macdonald & Evans Ltd., 540 pp. (75*s*.)

The importance of non-destructive testing to the engineering industry has now become so great that there can be few organizations that can afford to turn a blind eye to it. Until the publication of this book, there was no single volume in the English language that covered all the commonly used methods in reasonable detail.

The writing of a book on non-destructive testing is far from easy, as an author must constantly bear in mind the potential readership: people of widely different educational standards and widely different interests are involved, and it is, therefore, practically impossible to write a single book that will meet all needs. In the work under review, the author has taken this hurdle exceptionally well, and may be said to have provided something for everybody, although the emphasis is on the testing of castings rather than welds. He has ranged over history, theory, application, and interpretation and has drawn widely from his own very extensive practical knowledge. He has done all this in a most lucid manner which assumes no prior knowledge of the subject and only the most elementary knowledge of mathematics. To assist in this lucid exposition, he has included no fewer than 390 illustrations, a number of which are taken from sales literature on non-destructive testing equipment. For the advanced reader, who may wish to go into particular matters in greater detail, reference is made to a number of British Standards documents and to a wide range of literature.

However, notwithstanding the general high quality of the book, certain omissions and weaknesses have been noted and must be commented upon.

In considering the radiography of pipe butt welds, it is surprising to find that no reference is made to BS.2910:1957 —"Radiographic Examination of Fusion Welded Circumferential Butt Joints in Steel Pipes." The general arrangement for the application of the double-wall, double-image technique is illustrated in Fig. 8.46, but it is not stated that a single-image type of radiograph may be obtained with a similar arrangement merely by adjusting the orientation of the radiation beam with respect to the weld and the axis of the pipe. The text on page 159 infers that with the double-wall technique, a single-image radiograph can be obtained only by positioning the source of radiation close to the

(*Continued on p. 420*)

Welding

RESEARCH

Effects of Compressed and Oxygen-Enriched Air on the Flammability of Fabrics

By E. H. Coleman, F.R.I.C.

The effects of compressed air and of air enriched with oxygen on the flammability of a number of fabrics, including some treated with flame-retardants, have been examined.

The results show the extent to which the protection afforded by fabrics of low flammability is reduced in air enriched with oxygen or in compressed air. The effect of oxygen enrichment is greater than that of air pressure.

There are limits of oxygen concentration or air pressure above which fabrics burn however much retardant has been added, and also there are levels of retardant above which further additions do not materially improve the protection.

In certain industrial processes oxygen or compressed air is used, thereby increasing the concentration of oxygen available in the atmosphere for the combustion of flammable material. It is well known that the rate of combustion is increased by an increase of oxygen concentration but although notes on a demonstration in the United States have been published[1] there is little quantitative information concerning the extent of increase of the hazard.

In processes where a fire hazard exists it is customary for the workers to wear clothing of low flammability, such as thick wool or leather, and, if more flammable clothing such as cotton overalls are worn they are treated with flame-retardants. The performance and testing of such fabrics is the subject of a British Standard Specification.[2] This, however, refers to flammability in air, and there is no published information on the extent to which the protection is reduced by an increase of oxygen concentration.

Some experiments have been made therefore to examine and assess the effects of enriched and of compressed air on the flammability of some clothing fabrics.

This report was submitted by D. J. Rasbash, Secretary of the Committee on Industrial Fires and Explosions of the Fire Research Station, Boreham Wood. It is published at the request of the Director of the British Welding Research Association. 483

Experimental

The effects of oxygen-enriched air and of compressed air were measured by the changes of flame speed of strips of fabrics suspended in the required atmosphere. The fabrics selected were typical in weight and style of those used industrially (Table I). Before being tested the strips were conditioned for 24 hr in air at 67°F. and 67% relative humidity.

Tests in Air Enriched with Oxygen

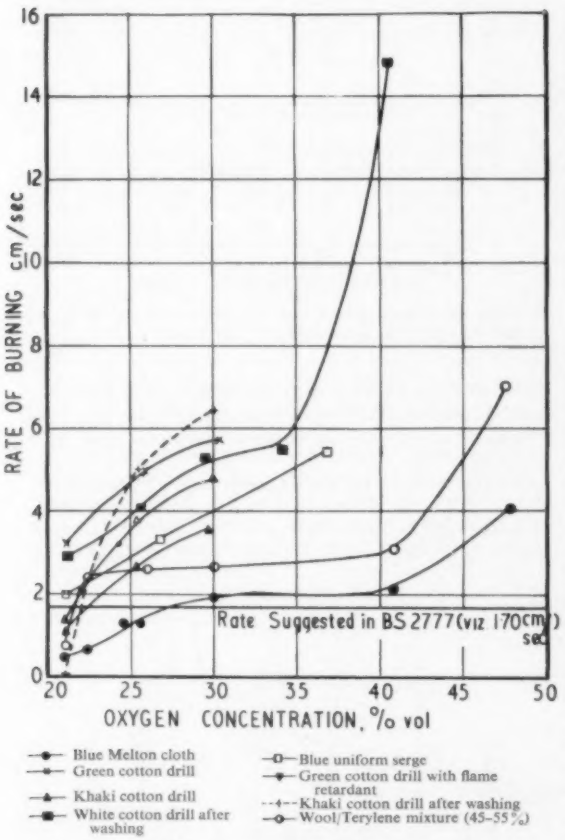
Apparatus and method

Specimens $1\frac{1}{2}$ in. × 72 in. (4 cm × 183 cm) were suspended from the arm of a torsion balance in a glass-fronted sheet steel cabinet 7 ft 6 in. high and 1 ft 0 in. square. Air mixed with oxygen was admitted at the

Table I

Fabrics used in flammability tests

Material	*Weight* oz/sq.yd.	g/sq.cm
Blue Melton wool cloth, waterproofed	21·8	0·0738
Blue wool serge cloth	15·7	0·0517
Wool/Terylene mixture, 45–55%	7·3	0·0247
Khaki cotton drill	10·4	0·0343
White unbleached cotton drill	9·6	0·0327
Green cotton drill	7·6	0·0256
Green cotton drill treated with flame-retardant	9·1	0·0309
P.V.C.-coated cotton cloth	16·2	0·0550


RATE OF BURNING cm/sec
OXYGEN CONCENTRATION, % vol
Rate Suggested in BS 2777 (viz 170 cm/sec)
Blue Melton cloth
Green cotton drill
Khaki cotton drill
White cotton drill after washing
Blue uniform serge
Green cotton drill with flame retardant
Khaki cotton drill after washing
Wool/Terylene mixture (45–55%)

1—*Variation of burning rate with oxygen concentration*

base and escaped at the top, the rate of flow being adjusted to 40 changes per hour, which gave a linear speed of 5 ft/min. or 0·06 mile/hr. This rate was considered to provide adequate oxygen for combustion but to be too slow to produce a 'forced draught' effect. The composition of the mixture was checked for each test by chemical analysis.

The flame speed was calculated from a photographic trace of the loss of weight with time, as in earlier work by Lawson *et al.*[3]

Results

The effects of oxygen concentration on vertical flame speed have been plotted in Fig. 1. In air the

Table II

Flame-retardants used for impregnating white cotton drill

A	30% boric acid H_3BO_3	70% borax $Na_2B_4O_7 . 10 H_2O$
B	60% boric acid H_3BO_3	40% trisodium phosphate $Na_3PO_4 . 12 H_2O$
C	60% boric acid H_3BO_3	40% disodium phosphate $Na_2HPO_4 . 12 H_2O$
D	60% boric acid H_3BO_3	40% monosodium phosphate $NaH_2PO_4 . H_2O$
E	60% boric acid H_3BO_3	40% monammonium phosphate $(NH_4) H_2PO_4$

woollen fabrics were difficult to ignite, and the strips burnt slowly for only a short distance. Cotton fabrics were easily ignited, and burnt more rapidly and usually to completion. A Terylene fabric melted and burning drops fell from the strips, but when it was blended with wool, the wool matrix supported the molten burning Terylene, and both were consumed. The flame speed of the mixture was comparable with that of a cotton drill. The P.V.C.-coated fabric and the retardant-treated green drill did not burn in air.

The flame speeds were increased when oxygen was added to the atmosphere, and, as shown in Fig. 2, the residues of carbon and ash decreased steadily.

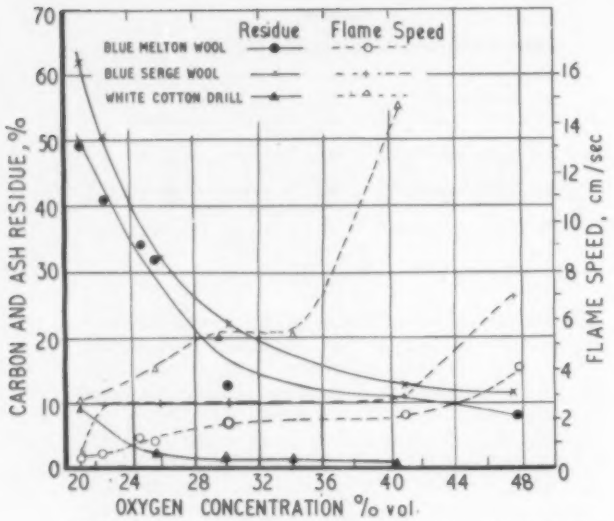
In the lower concentrations of oxygen it was noticed that, after ignition, a luminous flame ascended over the surface of the strip and was followed by a slower and less luminous flame. Combustion ceased when the upper flame was separated from the lower by more than 2–3 in. In higher oxygen concentrations, the distance and distinction between the flames lessened and the ash became lighter in colour. These changes are considered to indicate changes in the mode of burning, and may be responsible for the arrests or inflexions shown in Fig. 1, where flame speed is affected only slightly by the increases in oxygen content. Above about 40% oxygen concentration the flame speeds increased rapidly with increase of concentration.

The flame speeds of the woollen fabrics were increased by only slight additions of oxygen, and the strips burnt completely, although the flame speeds were very much lower than those of the cotton fabrics. P.V.C.-coated cloth burnt in only 26% of oxygen, and the performance was similar to that of a wool fabric of comparable weight. The flame-retardant treatment given to the green drill was effective in

Table III

Limiting values of weight of retardant and oxygen concentration

	Retardant		*Critical Limiting Values* Oxygen, vol. %	Retardant, wt. %
A	30% boric acid	70% borax	37	9
B	60% boric acid	40% trisodium phosphate	36	12
C	60% boric acid	40% disodium phosphate	28	14
D	60% boric acid	40% monosodium phosphate	24	19
E	60% boric acid	40% monammonium phosphate	28	25



2—*Variation of ash and flame speed with oxygen concentration*

air, but in 25·4% oxygen there was no significant difference between the treated and untreated fabrics.

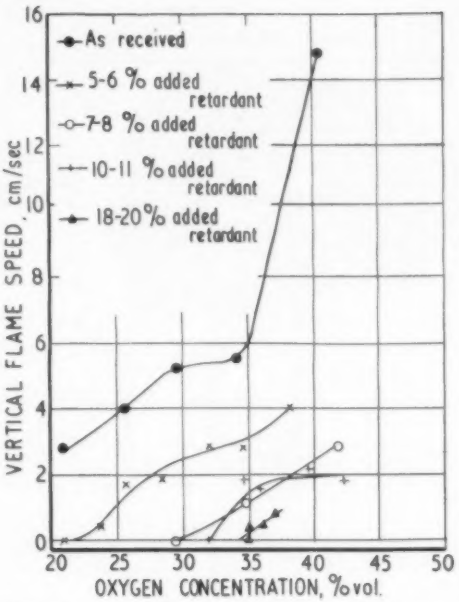
A British Standards Institution report[4] recommends that the flammability rating in air of fabrics should not be less than 150 sec for a vertical flame travel of 100 in., corresponding to a mean flame speed of 1·70 cm/sec. Figure 1 shows that with slight enrichment to 22½% oxygen only the blue Melton cloth would have satisfied this requirement, although it would have failed at 27½% oxygen.

Effect of oxygen enrichment on the flammability of fabrics impregnated with a flame-retardant

It is evident that a comparatively slight addition of oxygen to the atmosphere would be sufficient to reduce considerably the protection afforded by fabrics of low flammability in air, and experiments were therefore made to determine the degree of protection provided by flame-retardant treatments. The material used was the white unbleached cotton drill, and strips were impregnated by soaking them in solutions of mixtures of boric acid with borax or phosphates. These mixtures, listed in Table II, have been suggested by previous workers[4,5] (*A* and *B* in official publications).

In this report the degree of impregnation of the retardant is expressed as a percentage of the original weight of the fabric. Thus, with 10% impregnation 100 g of fabric would weigh 110 g after treatment. The results with the boric-acid/borax mixture are plotted in Fig. 3. They show that the protection afforded by the white drill with 7–8% retardant approximates to that of the blue wool serge, and with 10% approximates to the heavy Melton cloth.

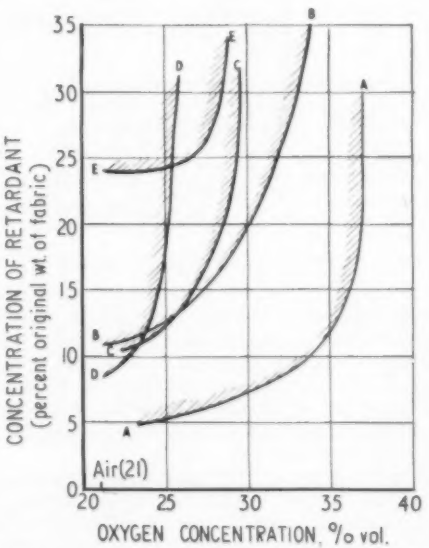
The use of vertical flame speed as a criterion to assess the effects of oxygen concentration and type and weight of retardant required the use of replicate strips with closely controlled weight of deposit. This was difficult to achieve with the facilities available and accordingly other criteria, more convenient experimentally, were used in tests comparing the effects of different retardants. The criteria were: (*a*) the oxygen



3—*Effect of oxygen enrichment on flame speed of white drill treated with 70% borax and 30% boric acid*

concentration above which the fabric burnt, however much retardant had been added; and (*b*) the weight of retardant above which further additions had little material effect.

The results of the tests to compare retardants are shown in Fig. 4. Strips with retardant concentrations, and in oxygen concentrations shown on the left-hand sides of the curves, did not burn, whereas those to the



4—*Critical concentrations of retardant and oxygen at limits of flammability. (See Table II for compositions.) The strips of impregnated fabric did not burn under conditions indicated on shaded sides of curves*

right burnt. For each mixture there was a critical level of retardant concentration above which further additions did not materially increase the degree of protection, and there was also a critical level of oxygen concentration above which the fabrics burnt whatever the weight of retardant. These critical values are given in Table III.

The boric-acid/borax mixture was more effective than any of the others at lower concentrations of retardant and in higher oxygen concentrations. The optimum weight of this mixture was very close to the 10% recommended in many publications, and would afford protection in atmospheres containing up to about 32% of oxygen. The limits of weight of deposit and oxygen concentration would be expected to vary with the weight of the fabric.

Tests in Compressed Air

Experiments were made to measure the effects of compressed air on flammability and to compare the effects with those of air enriched with oxygen.

Apparatus and method

The material used was the white unbleached cotton drill as used in the experiments with oxygen. It was not possible to pressurize the vessel used for the tests with oxygen, and the tests in compressed air were made with smaller specimens 6 in. × 0·4 in. (15 cm × 1 cm) suspended in a Perspex cylinder 24 in. high × 5·5 in. bore (60 cm × 14 cm) in which the air pressure could be raised to 75 lb/sq.in.

The effect of changing the conditions was measured by the time taken for complete combustion of the strip, measured visually, because it was not possible to introduce an automatic recorder into the cylinder. The combustion was started by a strip of celluloid 12 mm × 3 mm × 0·1 mm, attached to the bottom of the specimen, and ignited by a short length of 30 s.w.g. Nichrome wire heated electrically.

This experimental method was different from that previously used and thus it was not easy to make direct comparison with the earlier work because the observed burning times included the periods when the flame was building up and declining as well as the period of steady burning used as the criterion with the photographic trace. Accordingly, in addition to tests made in the vessel at a range of air pressures between atmospheric and 75 lb/sq.in., tests were made with specimens suspended in free air, and in atmospheres of air enriched with oxygen. In this last series, measurements were made both with the atmosphere stationary and in a current of enriched air flowing at 5 ft/min.

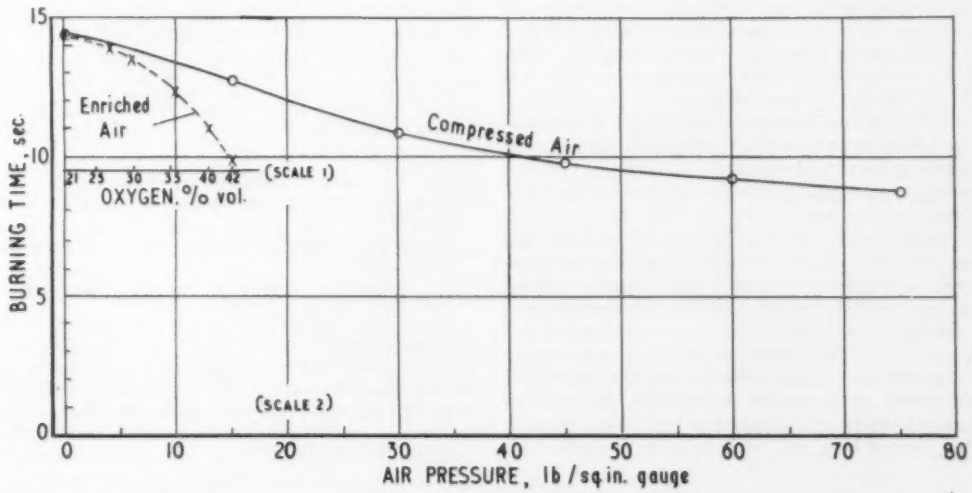
Results

The results of the tests are plotted in Fig. 5. The burning time of the fabric in the pressure vessel at atmospheric pressure was less than in free air, and also, with enriched air, the time was slightly less in stationary mixtures than in a current of enriched air. The effect may be associated with cooling effects of convection currents and the reflection of heat back on to the specimen from the surface of the Perspex cylinder.

Figure 5 shows that doubling the oxygen concentration from 21 to 42% by enrichment has produced a much greater effect than increasing the oxygen by doubling the air pressure to 2 atmospheres. Thus the effect of oxygen enrichment is much greater than that of air compression. This is probably because with compressed air the absolute value of diluent nitrogen is increased, whereas with oxygen enrichment the proportion of nitrogen is decreased.

Effect of compressed air on the burning times of fabrics impregnated with a flame-retardant

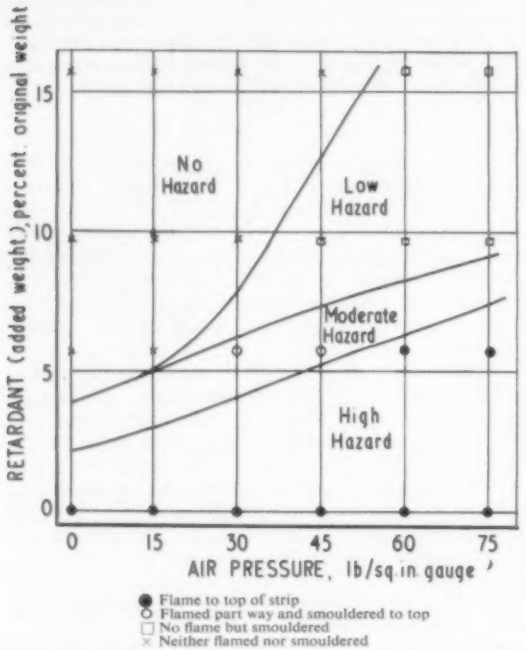
The tests with 183-cm strips in oxygen-enriched air showed that a mixture of 30% boric acid and 70% borax was superior to the other mixtures examined and accordingly this mixture was used to impregnate white



5—Burning time of white cotton drill in stationary atmospheres of compressed air and oxygen-enriched air. (Horizontal scales 1 and 2 have been adjusted so that the vol.% oxygen and air pressure represent identical absolute oxygen concentrations)

cotton drill to examine the behaviour of treated fabrics in compressed air.

The impregnated strips burnt in two stages. At first, a flame travelled up the strip and this was followed by a stage in which the residue smouldered until the specimen was consumed. The burning times have been plotted in Fig. 6 to show whether the strips burnt and whether combustion was by flaming or smouldering.



6—*Effect of air pressure on combustion of white cotton drill impregnated with mixture of 70% borax and 30% boric acid*

The ratios of flaming time to smouldering time were increased by increasing the air pressure, and decreased by increasing the weight of retardant. With 9·7 and 15·7% additions of retardants combustion was completely by smouldering. The burning time was not affected by increasing the weight of retardant from 9·7 to 15·7% and was reduced, with both concentrations, by increasing the air pressure. This is similar to the results obtained with oxygen, and as then, increasing the weight of boric-acid/borax above 10% affords little additional protection.

The results shown in Fig. 6 can be divided into groups: (*a*) of no hazard in which there was no burning; (*b*) those which burnt readily; and (*c*) and (*d*) those of moderate and low hazard in which combustion was partly or wholly by smouldering. In the low-hazard group, and to some extent in the moderate-hazard group, combustion would probably be slow enough to permit burning clothing to be removed or the fire to be extinguished before serious injuries had been inflicted, but there would be a risk of delayed fires from such causes as smouldering initiated by hot metal from welding and flame cutting. Therefore retardants for fabrics which are to be used in compressed air should be those which suppress smouldering.

At air pressures below about 38 lb/sq.in. the fabric impregnated with 10% of the boric-acid/borax mixture would be non-hazardous, and would constitute a low hazard up to about 80 lb/sq.in.

Conclusions

The experiments have shown the extent to which the rate of burning of fabrics is increased in air enriched with oxygen and in compressed air.

The results of tests in oxygen-enriched air showed that a white cotton drill treated with a flame-retardant would behave similarly to a heavy Melton cloth.

Several flame-retardants were examined, and of them the best was a boric-acid/borax mixture.

There are limits of oxygen concentration or air pressure above which fabrics burn however much retardant has been added, and there are also limits of retardant above which further additions do not materially improve the protection. The limits would be different with different fabrics and retardants.

In compressed air, strips impregnated with the boric-acid/borax mixture were divisible into groups according to whether or not the strips burnt and whether combustion was by flaming or smouldering. The group which only smouldered is considered to constitute a low hazard, intermediate between the safe, non-flammable group and the hazardous group which burnt with flaming, but it is desirable for protection in compressed air that the retardant should suppress smouldering or after-glow.

Increasing the oxygen concentration by enrichment produced a greater effect than by compressing the air.

Acknowledgments

The work described in this paper forms part of the programme of the Joint Fire Research Organization of the Department of Scientific and Industrial Research and Fire Offices' Committee; the paper is published by permission of the Director of Fire Research. The author wishes to thank Dr. F. E. T. Kingman for his suggestions and criticisms.

REFERENCES

1. W. J. Baldwin and J. A. Holiber: *Nat. Safety News*, 1957, vol. 76, pp. 26–27.
2. Flameproof industrial clothing (Materials and design): BS.1547:1949.
3. D. I. Lawson, C. T. Webster, and M. J. Gregsten: *J. Text. Inst.*, 1955, vol. 46, pp. T453–T463.
4. The flammability of apparel fabrics in relation to burning accidents: PD 2777:1957, British Standards Institution.
5. J. E. Ramsbottom: The fire-proofing of fabrics: Royal Aircraft Establishment, D.S.I.R., London, 1947, H:M.S.O.
6. R. W. Little: Flameproofing textile fabrics: American Chemical Society Monograph No. 104, New York, 1947, Reinhold Pub. Co.

B.W.R.A. REPORT

Compressive and Tensile Loading Tests on Joists with Web Stiffeners

By L. G. Johnson, M.A., A.M.I. STRUCT. E.

A series of tests was carried out to investigate the general problem of the design of web stiffeners for rolled steel joists subjected to compressive or tensile loads applied perpendicular to the flanges. In every case the stiffeners were welded in position and it is shown that the initial behavour of the test specimens is influenced quite appreciably by prestressing caused by the welding of the stiffeners. The effects of varying the sizes of both the stiffeners and the welds are described and various recommendations are made for use in design. Comparisons are made between the results obtained from the tests and the specifications in BS.449 for the design of web stiffeners.

THERE are many occasions, particularly in structural engineering, when it is found necessary to stiffen joist sections against either web buckling or crushing. A very common, and perhaps also the simplest, way of doing this is by means of mild steel plates shaped to fit the profile of the section and welded in position.

On a large job a detail such as this may occur frequently, and therefore any simplification in its design should result in an appreciable saving in both time and cost. The somewhat empirical method of design of web stiffeners laid down in BS.449 is rather limited in extent and it was felt that something might be gained by carrying out a series of tests on joists having various sizes of stiffeners and welds.

This report concerns the general problem of the design of web stiffeners and in particular the stanchion in the multi-storey steel frame. This work really forms part of the much wider problem of the plastic design of the rigid steel skeleton for the tall building. Such a building frame must have beam-to-stanchion connections capable of transmitting the full plastic moments of the members joined, and this is most efficiently carried out by means of welding. If I-sections are used for the columns, some form of web stiffening is usually essential, and the general considerations have been discussed in a previous paper.[1]

An attempt has been made to formulate a simple rule for the design of stiffeners and also to determine the minimum quantity of weld metal necessary for an efficient joint. In addition, the fabrication of the plate stiffener itself has been looked into with particular reference to the degree of fit before welding. Initially, tests were done on specimens whose stiffeners had been carefully machined to the correct profile, whereas later they were simply cut out by a profile burner and trimmed on a grindstone afterwards.

It must always be remembered, however, that simple compression and tension tests on the type of specimen described in this report do not accurately portray the conditions that exist in a rigid beam-to-stanchion connection. The web of the beam for instance considerably adds to the stiffness of the joint and at the same time carries the shear force. In spite of this it is considered that simple and inexpensive tests such as these do help in the understanding of the more complex problem just mentioned.

Experimental Work

All the specimens consisted of a 12 in. length of either 10×8 in.×55 lb RSJ or 8×8 in.×45 lb BFB with stiffeners across the centre line. Mild steel plates were welded to the outer faces of the flanges and in line with the stiffeners. Loading was applied through these plates. These loading strips were only 1 in. high for the compression specimens but they had to be 14 in. high for the tension specimens to suit the jaws of the testing machine. The set-up in the compression machine is clearly shown in Fig. 1, and Fig. 2 shows a tension specimen after removal from the tension machine. Specimens 1 to 18 inclusive were tested in compression and specimens 19 to 22 in tension.

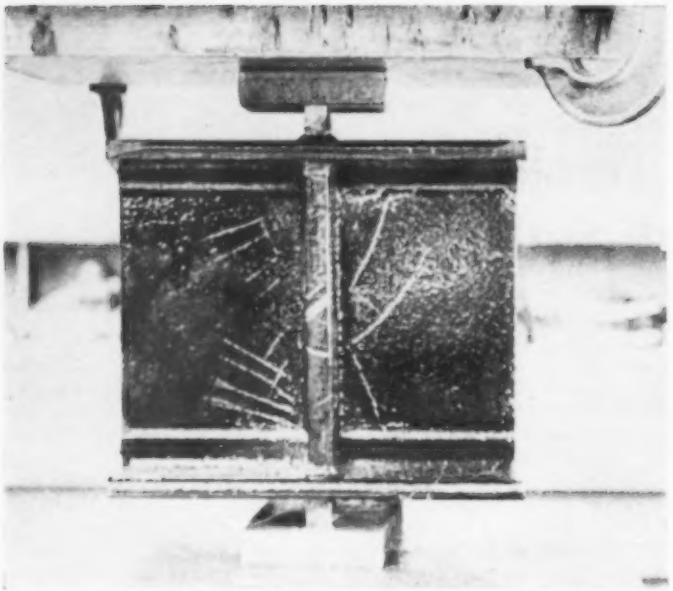
All the test pieces were coated with plumber's resin to show the attainment of the yield stress in any part of the joint. This is clearly seen on the photographs.

The stiffeners used in specimens 9, 11–18, and 22 were all cut out by a profile burner and were therefore

---

Report D1/8/58 of the British Welding Research Association, circulated to members in March 1959.

Mr. Johnson, formerly in the Department of Engineering at Cambridge University, is General Manager of the Skeleton Steel Co. Ltd., Stratford-on-Avon.



1—*Specimen 6 at 100 tons, showing method of loading in compression*

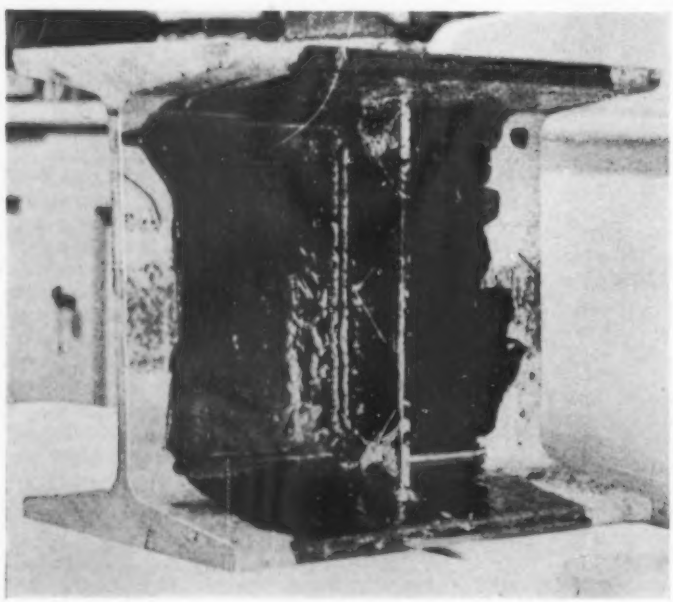
quite a loose and inaccurate fit. All other stiffeners were carefully machined to the exact profile of the beam. The act of welding naturally caused appreciable contraction of the specimens, with pre-stressing of both joists and stiffeners. This shrinkage was so pronounced that the loosely fitted stiffeners quickly became a very tight fit indeed.

The welding was carried out by an experienced welder under normal workshop conditions. All the welds were laid in the downhand position using class E.319 and E.217 electrodes. It is perhaps significant that there was not a single weld failure throughout the whole series of tests.

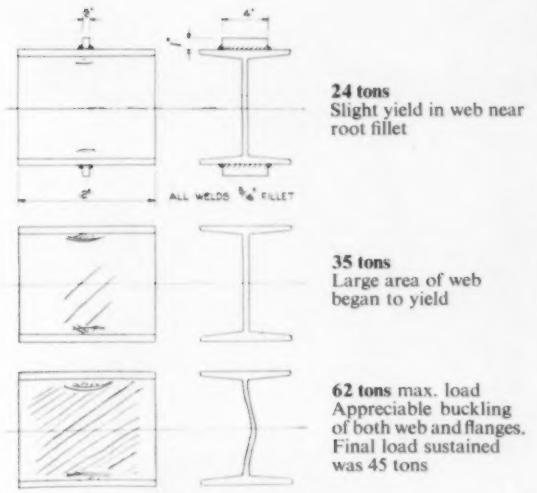
Amsler hydraulic testing machines were used for both compressive and tensile loading, the former having a capacity of 500 tons and the latter 200 tons.

Specimen 1 (Fig. 3)

This was a simple compression test on a joist without stiffening. Load was applied to the flanges through $4 \times \frac{1}{2}$ in. mild steel strips centrally positioned, and it was found that the web began to yield at a load of 24 tons. This yielding took place adjacent to the root fillet and directly under the loading points. Dial gauges for measuring flange deflections did not prove



2—*Specimen 19 at 57 tons*

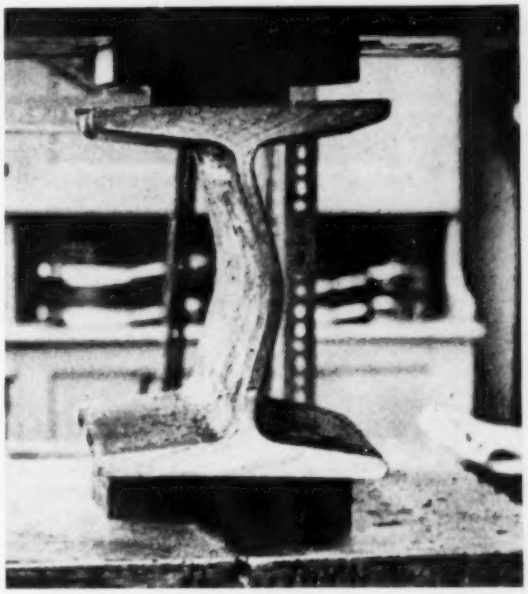


24 tons
Slight yield in web near root fillet

35 tons
Large area of web began to yield

62 tons max. load
Appreciable buckling of both web and flanges. Final load sustained was 45 tons

3—Specimen 1—10×8 in.×55 lb RSJ with no stiffeners, tested in compression



4—Specimen 1 at the final load of 45 tons

to give any valuable information and they were not used in subsequent tests.

When the load had increased to 35 tons the middle of the web was also showing signs of distress but there was no significant deformation. Further loading was applied; when 50 tons was reached there was appreciable bending of the flanges, and at 55 tons the web began to buckle. The maximum load attained was 62 tons at which point the web collapsed and the load dropped back, the final load being 45 tons. Fig. 4 shows the buckled web at the final load of 45 tons.

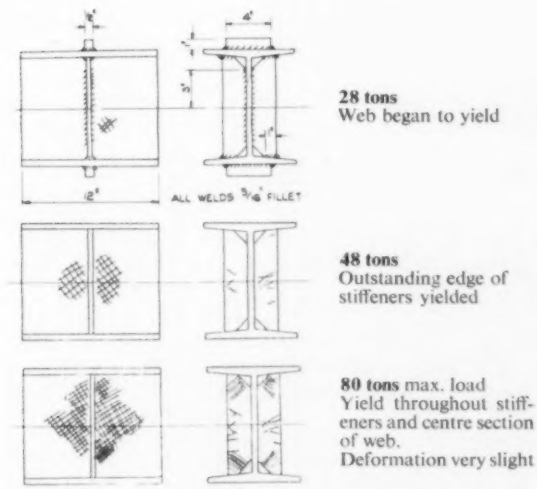
Specimen 2 (Fig. 5)

In this case 2×¼ in. web stiffeners, notched to clear the root fillets, were added, otherwise the details were exactly as for specimen 1. The first signs of yield occurred at a load of 28 tons. They appeared in the web but not adjacent to the root fillets. As the load was increased the yielding of the middle of the web continued to spread but not until 48 tons had been reached did the stiffeners exhibit any signs of being stressed beyond the elastic limit.

Further loading produced yielding throughout both web and stiffeners but no buckling or local deformation. At 80 tons the test had to be stopped because the 4×½ in. loading strips were beginning to tilt, being stressed up to approximately 40 tons/sq.in.

Specimen 3 (Fig. 6)

This was a repeat of specimen 2 but with the stiffeners moved out ¾ in. from the face of the web to

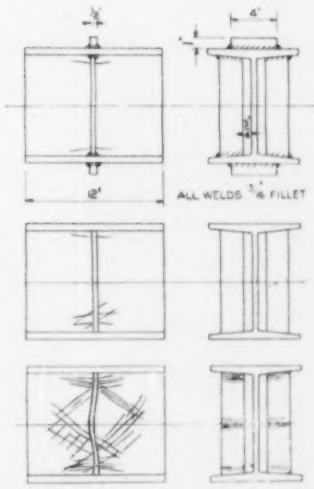


28 tons
Web began to yield

48 tons
Outstanding edge of stiffeners yielded

80 tons max. load
Yield throughout stiffeners and centre section of web.
Deformation very slight

5—Specimen 2—10×8 in.×55 lb RSJ with 2×¼ in. stiffeners, tested in compression

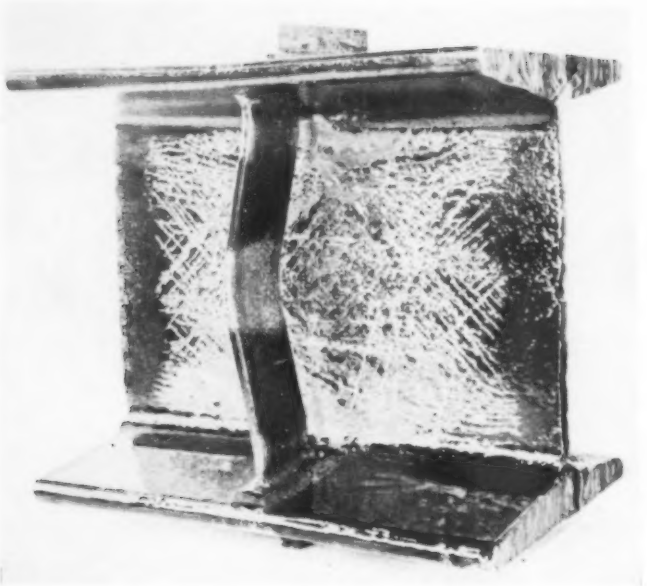


32 tons
Yield in web near root fillets

56 tons
Slight evidence of yield in one stiffener

62 tons max. load
Sudden collapse of stiffeners

6—Specimen 3—10×8 in.×55 lb RSJ with 2×¼ in. stiffeners, tested in compression



7—Specimen 3 at 62 tons

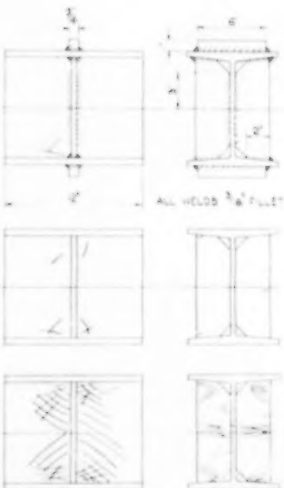
clear the root fillets. The initial yielding of the web was in the vicinity of the root fillets and occurred at a load of 32 tons. The stiffeners, however, showed no signs of yielding until a load of 56 tons had been reached.

Soon afterwards, the stiffeners became unstable and they buckled at a load of only 62 tons (Fig. 7). Comparison of these results with those obtained from specimen 2 shows that the carrying capacity is greatly increased when the stiffeners are welded to the web of the joist. This is only to be expected with such slender stiffeners, but the test was made to determine precisely what this difference in ultimate strength would be.

Specimen 4 (Fig. 8)

In this specimen the stiffeners were increased in section to $3 \times \frac{1}{2}$ in. and the loading strips were made $6 \times \frac{3}{4}$ in. Continuous $\frac{3}{16}$ in. fillet welds were used throughout.

Even with these much larger stiffeners the web began to yield at a load of 27 tons. The stiffeners were not affected until 60 tons had been reached. From then onwards the cracks in the resin continued to spread until, by the time the load had risen to 100 tons, they covered the whole of the central portion of the specimen. At this load there was no indication that the stiffeners were in any danger of collapse and the 100 ton load was sustained without difficulty.

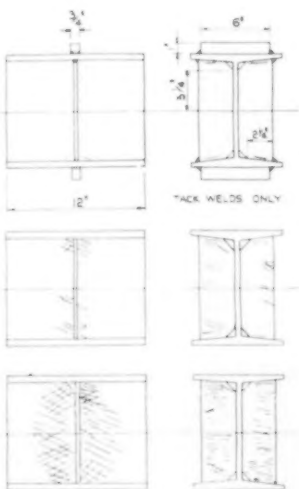


37 tons
Slight yield in web near root fillet

60 tons
Yield began in stiffeners

100 tons max. load
Yield throughout web and stiffeners.
Deformation quite insignificant

8—Specimen 4—10 × 8 in. × 55 lb RSJ with 3 × ½ in. stiffeners, tested in compression



60 tons
First sign of yield in web and stiffeners

75 tons
Still comparatively little yield in web

95 tons max. load
Stiffeners beginning to buckle

9—Specimen 5—10 × 8 in. × 55 lb RSJ with 3 × ½ in. stiffeners, tested in compression

Specimen 5 (Fig. 9)

Specimen 5 was exactly the same as specimen 4 except that the stiffeners and loading strips were fixed in position merely by tack welding to the flanges of the joist. In other words this was an attempt to determine the effect of the welding on the behaviour of the test piece.

Two main differences were observed. The first was that the web of the joist did not begin to yield until a load of 60 tons had been reached, compared with the corresponding figure of 37 tons for specimen 4. Secondly, it was noted that the stiffeners appeared to have been much more affected by increases in load than was the web.

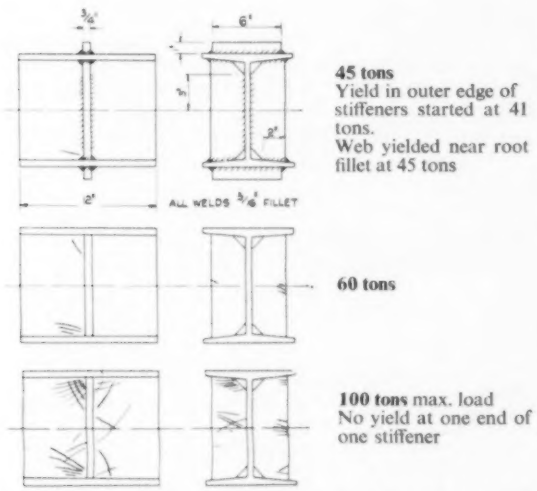
These facts tend to indicate that the welding of the stiffeners induces a compressive stress in the web which is higher than that in the stiffeners. This means in effect that the specimen contracts during the welding process and a compressive stress is present before any actual external loading is applied. The magnitude of this initial stress must be very variable and difficult to determine with any degree of accuracy.

The maximum load carried was 95 tons, at which point the stiffeners began to buckle, because they were not connected in any way to the web of the joist.

Specimen 6 (Fig. 10)

The only difference between this specimen and specimen 4 was that the stiffeners were increased in thickness from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. It was observed that the initial yield took place at loads of 41 and 45 tons in the web and stiffener respectively. These initial values therefore were little, if any, improvement over those obtained for specimen 4.

At a load of 100 tons, however, the yielded zones were not as extensive as they were in specimen 4; the initial behaviour was thus similar, but at higher loads the additional stiffness provided by the thicker stiffeners became apparent.

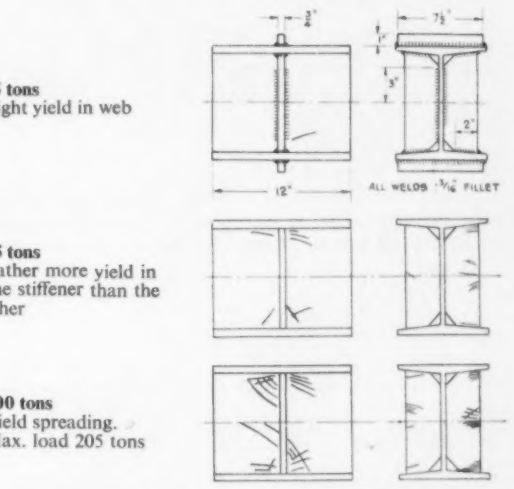

45 tons
Yield in outer edge of stiffeners started at 41 tons.
Web yielded near root fillet at 45 tons
60 tons
100 tons max. load
No yield at one end of one stiffener

10—*Specimen 6—10×8 in.×55 lb RSJ with 3×¾ in. stiffeners, tested in compression*

Specimen 7 (Fig. 11)

This was a repeat of specimen 6 but with the loading strips increased from 6×¾ in. to 7½×1 in. The object of the test was to determine the ultimate carrying capacity of the joist with 3×¾ in. web stiffeners.

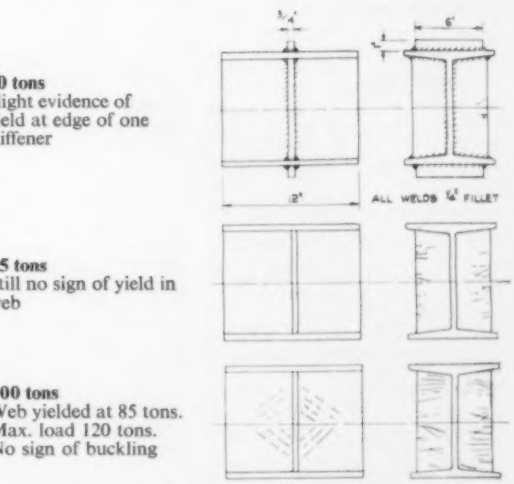
As was only to be expected the initial behaviour was very similar to that of specimen 6. The final load attained was 205 tons, at which value the flanges were bending and the stiffeners beginning to buckle. It was perhaps rather significant that the final load was approximately four times as big as that which produced the initial yielding of the web.



11—*Specimen 7—10×8 in.×55 lb RSJ with 3×¾ in. stiffeners, tested in compression*

Specimen 8 (Fig. 12)

This specimen was a simple modification of specimen 6, the stiffeners being made to fit closely into the


30 tons
Slight evidence of yield at edge of one stiffener
75 tons
Still no sign of yield in web
100 tons
Web yielded at 85 tons.
Max. load 120 tons.
No sign of buckling

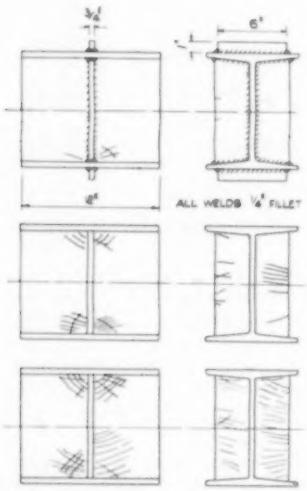
12—*Specimen 8—10×8 in.×55 lb RSJ with 3×¾ in. stiffeners, tested in compression*

root fillets instead of being notched, and the welds being increased from $\frac{3}{16}$ to $\frac{1}{4}$ in. fillets. The stiffeners were machined very accurately to fit the inner joist profile.

Loading soon revealed that there must have been quite appreciable pre-stressing, because the outer edge of one stiffener showed signs of yielding at only 30 tons. Further loading produced evidence of yield throughout both stiffeners, but not until the load had been raised to 85 tons was there any sign of yield in the web. When this did in fact take place it was in an area near the middle of the web and not adjacent to the root fillets as in specimen 6. At the maximum load applied, 120 tons, the whole joint was still quite rigid.

Specimen 9 (Fig. 13)

In this case specimen 8 was reproduced but with the stiffeners cut out by means of a profile burner instead of being machined to fit the outline of the joist.

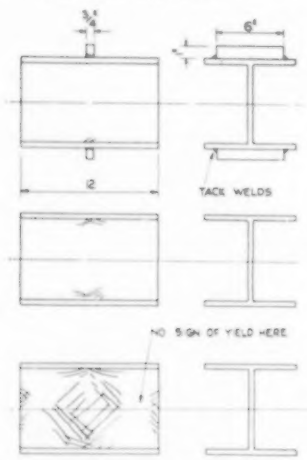


51 tons
Slight yield in web and one stiffener

75 tons
Appreciable yielding of both web and stiffeners

100 tons
Max. load 120 tons. No sign of buckling

13—*Specimen 9—10×8 in.×55 lb RSJ with 3×¾ in. stiffeners, tested in compression*



17 tons
First signs of yield near root fillet

30 tons
No sign of yield in centre of web

40 tons
Max. load 55 tons when web buckled

14—*Specimen 10—8×8 in.×45 lb BFB with no stiffeners, tested in compression*

Before welding, the edges of the stiffeners were trimmed on a grindstone. The degree of fit was such that in places there were gaps of almost $\frac{1}{32}$ in. between the plate stiffener and the face of the joist.

The fact that the stiffeners of specimen 9 were a much looser fit than those of specimen 8 was well illustrated by the relative behaviour under test. Both web and stiffeners yielded at 51 tons on specimen 9 whereas the corresponding loads for specimen 8 were 85 and 30 tons respectively. The pattern too was different because the yielding in the web of specimen 8 was confined to the central area but it started near the root fillets in specimen 9.

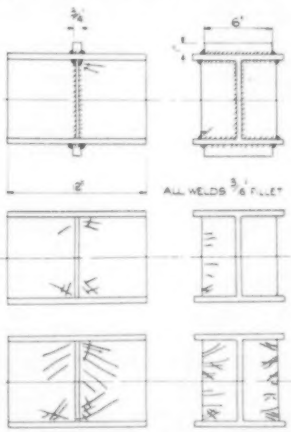
It seems therefore that the use of loosely fitting stiffeners results in earlier yielding of the web but later yielding of the stiffeners. At the maximum load of 120 tons the rigidity of both specimens was found to be much the same.

Specimen 10 (Fig. 14)

This was a simple lateral compression test on a 12 in. length of beam having no web stiffeners. The first regions of yield occurred immediately below the loading strips near the root fillets at a load of 17 tons. Cracks in the resin continued to spread as the load was increased until, at 40 tons, they covered almost the whole of the web. At this stage there was very little distortion of the flanges and no sign of web buckling. The maximum load attained was 55 tons, at which stage the web began to collapse and the load fell away rapidly.

Specimens 11 and 12 (Fig. 15)

Specimens 11 and 12 were almost identical. Both pairs of stiffeners were cut out by a profile burner but those of specimen 11 were notched to clear the root fillets whereas the others on specimen 12 were a complete fit. The behaviour under test was much the same in both instances. Initial yielding of both web and stiffeners took place at a load of 20 tons, the stiffeners themselves began to buckle at about 75 tons and the maximum load attained was approximately 100 tons. Collapse of the stiffeners and bending of the flanges then took place with little web deformation.



20 tons
Slight evidence of yield in both web and flange

30 tons
One stiffener still showing no sign of distress

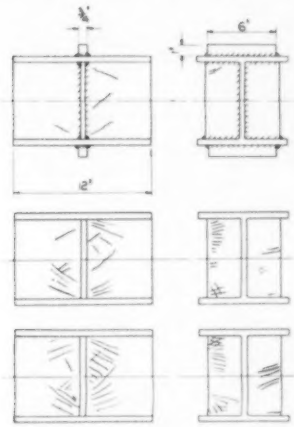
50 tons
At 75 tons stiffeners began to buckle and at 100 tons collapse occurred

15—*Specimen 12—8×8 in×45 lb BFB with 3×¼ in. stiffeners, tested in compression*

Specimens 13 and 14 (Fig. 16)

These two specimens were also of the same construction except that number 13 had stiffeners which were notched to clear the root fillets. Again the stiffeners were cut to shape by a profile burner.

Both sets of test results were almost identical, the first signs of yield occurring at the rather low figure of about 30 tons. Continued loading resulted in yield



30 tons
Part of web and one stiffener showed signs of yield

50 tons

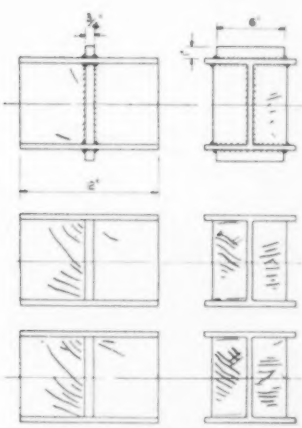
70 tons
Stiffeners began to buckle at 115 tons. Max. load 170 tons

16—*Specimen 14—8 × 8 in. × 45 lb BFB with 3 × ½ in. stiffeners, tested in compression*

throughout both web and stiffeners at a load of approximately 100 tons, the stiffeners themselves beginning to buckle at 115 tons. The final load reached was 170 tons.

Specimens 15 and 16 (Fig. 17)

This pair corresponded exactly with specimens 13 and 14 except that the thickness of the stiffeners was increased from ½ to ¾ in. The overall behaviour of the two specimens was in quite close agreement except for the load to produce initial yielding, which was 48 tons for number 15 and 33 tons for number 16. Throughout both tests it was evident that the beams were extremely



33 tons
Signs of yield in web and one stiffener

60 tons

80 tons
Max. load 215 tons. One stiffener did not yield until load was 90 tons

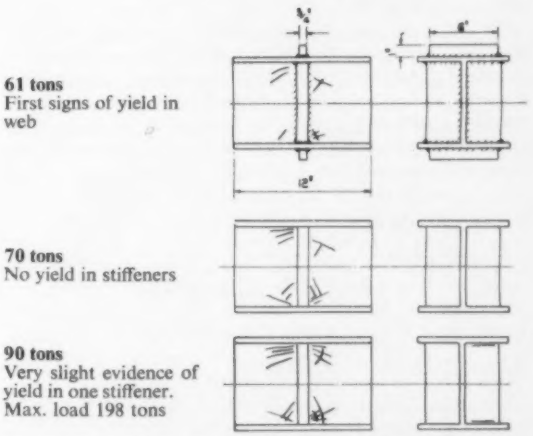
17—*Specimen 16—8 × 8 in. × 45 lb BFB with 3 × ¾ in. stiffeners, tested in compression*

rigid—the final loads reached were 227 and 215 tons respectively. Even then the weakness was not really in the joint but in the 6 × ¾ in. loading strips which tilted and caused the specimens to slip over to one side. There was, however, a certain amount of bending in the specimens themselves but they were by no means on the point of collapse.

Specimens 17 and 18 (Fig. 18)

The stiffeners in these two specimens were of 3 × 1 in. section burned to profile with the corners notched to clear the root fillets on number 17 only. As was to be expected the connections proved to be very rigid and they each sustained a load of slightly less than 200 tons. At this figure the loading began to fall off owing to local collapse of the 6 × ¾ in. strips, the beams and stiffeners themselves having suffered comparatively little deformation.

Initial signs of yielding took place at about 60 tons and occurred in both web and stiffeners almost

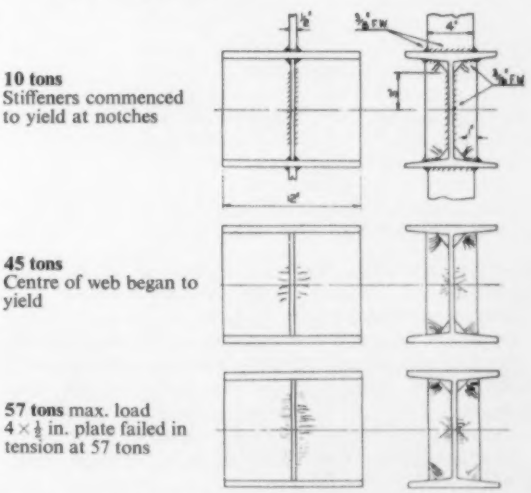


61 tons
First signs of yield in web

70 tons
No yield in stiffeners

90 tons
Very slight evidence of yield in one stiffener. Max. load 198 tons

18—*Specimen 18—8 × 8 in. × 45 lb BFB with 3 × 1 in. stiffeners, tested in compression*



10 tons
Stiffeners commenced to yield at notches

45 tons
Centre of web began to yield

57 tons max. load 4 × ½ in. plate failed in tension at 57 tons

19—*Specimen 19—10 × 8 in. × 55 lb RSJ with 2 × ½ in. stiffeners, tested in tension*

simultaneously. As the loading was increased, however, the web was affected much more than the stiffeners. At 90 tons there was appreciable evidence of yielding in the web but only slight traces in the stiffeners.

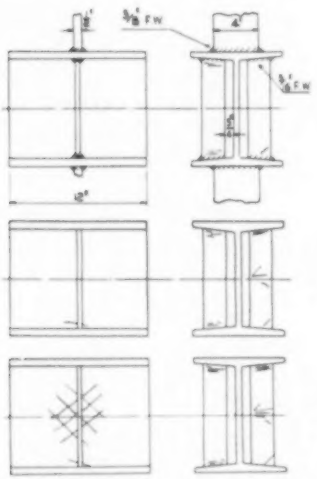
Specimen 19 (Fig. 19)

This specimen was exactly the same as specimen 2, which had been tested in compression. The behaviour of the two joints was quite different, however, as can be seen by comparing Fig. 5 with Fig. 19. Under tensile loading there were signs of yield in the stiffeners when the load was as low as 10 tons but not until the load was increased to 45 tons was there any yielding of the web. The compression member behaved in precisely the opposite manner, the web being affected long before the stiffeners. This seems to indicate that the welding process induces a compressive stress in the web which exceeds that in the stiffeners.

At a load of 57 tons one of the $4 \times \frac{1}{2}$ in. wing plates failed in tension, all the welds remaining intact.

Specimen 20 (Fig. 20)

This was a simple modification of specimen 19. The web stiffeners were moved out to a position $\frac{3}{4}$ in. from the face of the web and hence there was no need for them to be notched at the ends to clear the root fillets. The alteration resulted in a change in the behaviour under test in that the initial yielding of the stiffeners was not observed until a load of 33 tons had been



33 tons
Slight yield at ends of stiffeners

50 tons
Slight evidence of yield in web near root fillet

59 tons max. load
$4 \times \frac{1}{2}$ in. plate failed in tension at 59 tons

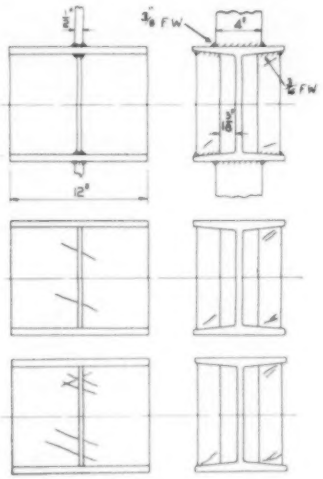
20—Specimen 20—10 × 8 in. × 55 lb RSJ with $2 \times \frac{1}{4}$ in. stiffeners, tested in tension

applied, compared with the figure of 10 tons for specimen 19. This is easily explained when it is remembered that the induced compressive stress in the web would be much less in specimen 20 owing to the complete absence of welding between stiffeners and web. Apart from this solitary variation the two members behaved in a very similar manner, the maximum load being 59 tons for specimen 20. Failure was again due to a tensile fracture in one of the $4 \times \frac{1}{2}$ in. loading plates.

A similar joint tested in compression was specimen 3, and Fig. 6 should be compared with Fig. 20. The main difference is the much earlier yielding of the stiffeners in specimen 20.

Specimen 21 (Fig. 21)

In this case the $2 \times \frac{1}{4}$ in. stiffeners were moved outwards to a position $1\frac{3}{8}$ in. from the face of the web of the joist. The test results were very similar to those



33 tons
Yielding at ends of stiffeners

55 tons
Slight yield in web

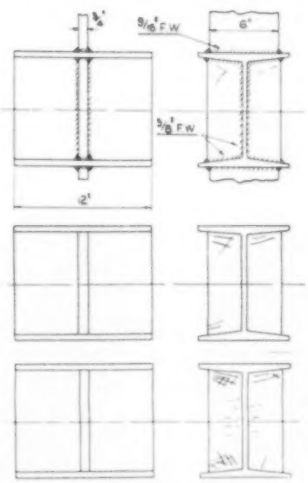
58 tons max. load
$4 \times \frac{1}{2}$ in. plate failed in tension at 58 tons

21—Specimen 21—10 × 8 in. × 55 lb RSJ with $2 \times \frac{1}{4}$ in. stiffeners, tested in tension

obtained for specimen 20, the initial yielding of the stiffeners occurring at a load of 33 tons followed by the failure of one of the $4 \times \frac{1}{2}$ in. loading plates at 58 tons. All the welds remained intact.

Specimen 22 (Fig. 22)

This specimen had $3 \times \frac{3}{4}$ in. stiffeners burned to suit the profile of the joist, and the wing or loading plates were increased to $6 \times \frac{3}{4}$ in. It was perhaps significant that there was no sign of yield in the web at any stage



60 tons
Stiffeners began to yield

75 tons
No sign of yield in web

100 tons
One $6 \times \frac{3}{4}$ in. plate failed at 130 tons.
No sign of yield in web even at failure

22—Specimen 22—10 × 8 in. × 55 lb RSJ with $3 \times \frac{3}{4}$ in. stiffeners, tested in tension

Table I

Summary of test results

Spec.	*Size, in.*	*Stiffener size, in.*	*BS. 449*	*Loads, tons* *1st Yield*	*Max.*	*Collapse*
Compression						
1	10×8	—	16	24	—	62
2	,,	2×¼	49	28	80	—
3	,,	,,	—	32	—	62
4	,,	3×½	68	37	100	—
5	,,	,,	—	60	—	95
6	,,	3×¾	81	41	100	—
7	,,	,,	81	55	—	205
8	,,	,,	81	30	120	—
9	,,	,,	81	51	120	—
10	8×8	—	10	17	—	55
11	,,	3×¼	44	20	—	100
12	,,	,,	44	20	—	100
13	,,	3×½	57	29	—	169
14	,,	,,	57	30	—	170
15	,,	3×¾	71	48	227	—
16	,,	,,	71	33	215	—
17	,,	3×1	83	60	193	—
18	,,	,,	83	61	198	—
Tension						
19	10×8	2×¼	—	10	57	—
20	,,	,,	—	33	59	—
21	,,	,,	—	33	58	—
22	,,	3×¾	—	60	130	—

of the test. The stiffeners began to yield at a load of 60 tons and they continued to be affected more and more as the load was increased. Finally, at a load of 130 tons, there was a tensile failure in one of the 6×¾ in. plates but this was not accompanied by fracture of any weld.

Again, it seems abundantly clear that the initial compressive pre-stressing of the web due to welding was responsible for the fact that the tensile stress induced by the external loading was kept below the yield value.

Summary of Test Results

A comparative summary of all the results is shown in Table I.

Compression members without stiffeners

Two tests were carried out on unstiffened members. The 10×8 in.× 55lb RSJ buckled at a load of 62 tons and the 8×8 in.×45 lb BFB at 55 tons. In both cases the initial yielding took place in the web near the root fillet, immediately below the loading points and at about one third of the collapse load. The behaviour of both test pieces was not in any way unusual and there is little to comment on except the fact that the permissible loads laid down by BS.449 were found to be about two thirds of the loads required to produce the initial yielding in the web. As a function of the collapse loads they were approximately one quarter and one fifth respectively.

Compression members with stiffeners

The first point of interest is illustrated by the behaviour of specimens 3 and 5. In both cases the stiffeners were not welded to the web of the joist, and in the initial stages this fact did not seem to be of much importance. As the loading was increased, however, it became abundantly clear that the stiffeners were going to buckle. This was only to be expected of course because of the high slenderness ratios; that of the 3×½ in. stiffeners, for example, was 56. It seems therefore to be absolutely essential to weld the stiffeners to the face of the web except possibly when very thick stiffeners are used. This is clearly demonstrated by the collapse of both specimens 1 and 3 at a load of 62 tons in spite of the fact that the latter was stiffened. The results obtained for specimens 2 and 4 reveal the considerable additional stiffness obtained by attaching the stiffeners of specimens 3 and 5 to the web of the joist.

Specimens 6–9 inclusive were all 10×8 in.×55 lb joists with 3×¾ in. stiffeners. There were small differences in the constructional details; 6 and 7 having notched stiffeners, and 9 having web stiffeners which had been cut out on a profile burner and in consequence were a much looser fit than those on specimens 6, 7, and 8. The looser type of stiffener resulted in earlier yielding of the web and later yielding of the stiffeners but the overall rigidity appeared to be much the same. All the stiffeners used in the first eight tests had been very carefully machined and fitted to the profile of the joists and this is a rather long and comparatively expensive operation. As the looser type of stiffener seemed to give similar test results to those of its much more costly counterpart it was decided to use this cheaper version on all subsequent tests except numbers 19, 20, and 21. The notching of the stiffeners too did not appear to make any difference to the behaviour under test. It thus seems that the plain stiffener without notches is preferable because this gives continuity of welding and is very simply cut out by a profile burner.

The permissible loads laid down by BS.449 for specimens with stiffeners (Table I) are all in excess of the loads which produce the initial yielding. In fact, some of these allowable loads are more than twice as big as those which are responsible for the early yielding in the specimens. It must be remembered of course that the induced compressive stresses due to welding are no doubt partly responsible for this state of affairs but the fact remains that the elastic method of design set out in BS.449 does not even remotely approximate to the actual conditions which exist in the connection. The use of this specification for the design of bearing stiffeners undoubtedly leads to safe results because the working and collapse loads represent a load factor which varies from 2·3 to 3·0. Any elastic conception of design, however, is quite false because the working loads all produce stresses far in excess of the elastic limit.

Tension members with stiffeners

Specimens 19 to 22 inclusive were tested in tension and they all gave similar results. Firstly, it was noticed that the stiffeners were affected at a much earlier stage than were the webs; indeed number 22 did not show any sign of yielding in the web even at the maximum load of 130 tons. The compression specimens did just the opposite in that the webs were affected before the stiffeners. This confirms the view, already mentioned,

that the welding process induces compressive stresses which are generally higher in the web than in the stiffeners.

It was also very significant that there was no weld failure in any of these four specimens. The $\frac{3}{8}$ in. and $\frac{9}{16}$ in. fillet welds proved themselves capable of taking a higher load than the $\frac{1}{2}$ in. and $\frac{3}{4}$ in. wing plates, which failed at stresses of the order of 29 tons/sq.in. When it is remembered that the shear stresses in the welds must also have been about 29 tons/sq.in., the generally accepted working value of 6·5 tons/sq.in. does seem to be unduly conservative.

Conclusions

(1) If stiffeners are welded to the web and inner faces of the flanges of a beam section, compressive stresses are induced which are indeterminate in magnitude but probably higher in the web than in the stiffeners.

(2) There is little to be gained by fabricating the stiffeners to such a high degree of accuracy that they are a perfect fit when offered up to the joist profile. Provided that the stiffeners do not have more than $\frac{1}{32}$ in. clearance before welding they are likely to be efficient.

(3) It is desirable to give lateral support to compression stiffeners by welding them to the face of the web, otherwise there is danger of local buckling owing to the comparatively large slenderness ratios.

(4) The use of the design method set out in BS.449 will usually give working loads which are sufficient to cause yielding in the joint in several places. The actual load factor, however, is likely to be between 2·3 and 3·0.

(5) With the type of compression loading used in this series of tests, purely nominal weld sizes can be employed with complete confidence.

Acknowledgments

The whole of the work described in this report was undertaken at the Engineering Laboratory, Cambridge University, under the direction of Professor J. F. Baker, Head of the Department of Engineering. It forms part of a general investigation being carried out at Cambridge into the behaviour of steel structures in the plastic range, with the support of the British Welding Research Association.

Thanks are due to J. E. Aspinall and G. W. Jordan who were attending the post-graduate course on Structures and Strength of Materials at Cambridge University and during this period helped to carry out the tests and made many useful suggestions. A very complete set of photographs was taken by Mr. Jordan and a number of these were used to illustrate the original report.

REFERENCES

1. L. G. JOHNSON: *Brit. Weld. J.*, 1959, vol. 6, pp. 38–46.
2. BS.449:1948, "The use of structural steel in building."

NON-DESTRUCTIVE TESTING

(*Continued from p. 405*)

pipe wall, opposite the portion of the weld under examination (Fig. 8.47). This latter technique would not be considered very satisfactory for a critical examination, unless the pipe were of very large diameter, and the radiation source very small. A similar comment applies to the use of the source inside the pipe, as illustrated in Fig.8.49.

Considering next the radiography of butt welded plates, the British Standards document on this subject, BS.2600: 1955, is merely referred to in a general discussion on weld inspection on page 41, and no subsequent reference is made to it in the appropriate chapter on radiographic technique.

Penetrameters, which figure very prominently in weld radiography, are only very briefly considered, and only the B.W.R.A. type is indicated in the chapter on radiographic technique. It is not made clear that in using this penetrameter to assess radiographic quality, the visibility of the holes in the steps, and not merely the visibility of the steps themselves should be considered. The D.I.N. penetrameter is only accorded incidental mention on page 384 in the course of a quotation from a paper by Nemet and Cox on the X-ray image intensifier. It is nowhere stated that for a given radiographic quality, widely different values of percentage sensitivity are given by these two penetrameters.

Special techniques for the radiography of light alloys are not discussed at any length, but by way of compensation a detailed technique is given for the radiography of heavy chunks of stone at Stonehenge!

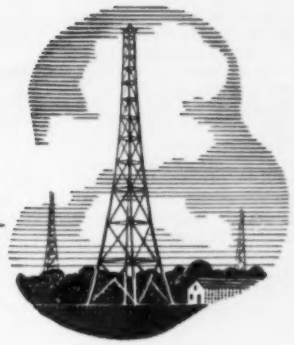
The remaining principal methods of non-destructive testing, *viz.*, ultrasonics, magnetic, penetrant, and eddy current, all receive their fair share of attention, and X-ray diffraction and neutron radiography are also included. However, there is an unfortunate lack of critical assessment of the scope of the principal methods.

Typographical errors are very few, although on page 69, Table I, the micron is incorrectly stated to be 10^{-3} instead of 10^{-4} cm. Some decimal points have been omitted on pages 148 and 149, but these can be readily spotted.

The experienced worker will find this book a valuable source of reference, while the newcomer to the subject will find it a most readable and interesting instructional manual.

H. L. CARSON

NEWS
and Announcements



News of the Institute and Branches
B.W.R.A. · Other Societies ·
and Industry

INSTITUTE ACTIVITIES

Electro-Slag Welding

Two papers describing recent developments in this process will be presented at an afternoon meeting of the Institute on 1st October, beginning at 2.30 p.m. **Admission will be by ticket,** and members are invited to make early application to the Secretary for no separate notices will be distributed.

One of the papers is published in this issue of the Journal; the other will be available in duplicated form before the meeting.

Autumn Meeting 1959

Nearly fifty members of the French Society of Welding Engineers have enrolled for the joint meeting to be held at the Institute from 3rd–6th November next.

French visitors will be going to the Laboratories of the British Welding Research Association at Abington, or to the works of A.P.V. Company at Crawley on Tuesday, 3rd November, and on the following day they will have the choice of visiting the Research Laboratories of Murex Welding Processes Ltd. at Waltham Cross, or the works of G. A. Harvey at Greenwich. These visits will be open only to the Institute's French guests.

For members of the Institute the meeting will open on the evening of Tuesday, 3rd November, when the President, Mr. E. Seymour-Semper, will deliver his Presidential Address at 54 Princes' Gate at 6.30 p.m. Tea will first be served, and there will be a Reception after the Address for the French guests and ticket holders. Tickets (£1) will be available from the Secretary.

On the following day, Wednesday 4th November, there will be the Annual Dinner at the Park Lane Hotel, at 7.15 for 7.45 p.m. Tickets for the Dinner will be on sale at the end of September.

The mornings and afternoons of Thursday, 5th and Friday 6th November will be occupied by discussion meetings at the Institute, for which fifteen papers have been promised, seven by French and eight by British authors.

The discussion will be conducted in both English and French, with an interpreter. The papers are all being pre-printed in the journals of the two co-operating bodies. The October issue of *B.W.J.* will contain all of the eight British papers in full, together with summaries in English of the French papers. *Soudage et Techniques Connexes* will publish the French papers in full and French summaries of the British papers. Copies of all these will be distributed to those who enrol for the meeting, but because of the dispute in the printing industry and the delay in publication of the Journal as a result, members will not receive their copies of the October issue of the *B.W.J.* before the middle of October.

Annual Dinner 1959

The Annual Dinner of the Institute will be held at the Park Lane Hotel, Piccadilly, London W.1, at 7.15 for 7.45 p.m. on Wednesday, 4th November. As usual, parties of eight or more may reserve tables, and parties of seven or less will be seated together.

Tickets will be on sale at the end of September, obtainable from the Secretary. In view of the heavy demand and the limited accommodation, early application is strongly advised.

Premises

During the summer, extensive alterations and improvements have been made in the basement of the Institute's offices at 54 Princes' Gate. A large room under the terrace at the back of the house has been reconditioned as a refreshment room, and is equipped for demonstrations during Courses of the School of Technology. Some additional office accommodation has been provided for the technical staff in the front of the basement, and redecoration of the basement corridor has greatly improved its appearance.

It will now no longer be necessary to use the Library for the service of refreshments during School Courses. New furniture has been installed there, and readers wishing to work at the Institute will find the conditions much improved.

Publications

The Institute has recently published a 2nd edition of List 1:1959 "*Consultants, Site Investigation Services, Industrial Welding Schools, and Testing Laboratories*". This brings up to date this useful list of names and addresses of persons and organizations whose services are available to members who need information or assistance outside the scope of the Institute's Library and Technical Information services.

Copies of the booklet may be obtained, free, from the Secretary.

Russian Scientist to Lecture

The Institute is proud to announce that Professor N. N. Rykalin, Dr.techn.sci., Corresponding member of the USSR Academy of Sciences, will be visiting the United Kingdom at the invitation of the Institute and will lecture at the School of Welding Technology on 29th and 30th September, and at the special meeting on Electro-Slag Welding on 1st October.

NEWS OF MEMBERS

I. Levin has retired from the Board of Messrs. T. C. Jones & Co. Ltd., and has joined the Boards of The General Steel & Iron Co. Ltd., and G. R. Turner Ltd.

W. E. Bryant has relinquished his appointment as Sales Superintendent of Weldcraft Ltd., a member of the G. D. Peters Group, and has joined Barker Machine Tool and Equipment Ltd. as Sales Manager for the Welding Division.

R. T. Bromfield, who has been General Manager of Invicta Electrodes Ltd. for several years, has now been appointed Managing Director of the Company.

A. R. Heaton has taken up an appointment with the Consett Iron Company.

SCHOOL OF WELDING TECHNOLOGY

Three new courses have been arranged for the beginning of next year.

The first, a course for **Ultrasonic Operators,** will be held from 4th–15th January 1960. Ultrasonic methods of examination are finding more and more applications for the inspection of welded products, but the interpretation of records and the actual

technique of operation still require skill and an expert knowledge of the method. This is a special two-week training course for those who actually use ultrasonic equipment.

The second course, to be held from 8th–14th February, deals with the **Welding of Atomic Energy Plant**, and is planned for engineers, designers, and metallurgists to provide the latest information on the problems met with in this rapidly developing field of construction, and in which welding plays such an important part.

There is also to be a third brief course, of a different character, on **Welding for Junior Management.** Discussions at the Institute's Spring Meeting this year showed that there are still many problems of management in the effective and economic use of welding for construction.

This four-day course, from 22nd–25th February, is designed to explain to those holding junior positions in management some of the factors affecting the proper application of welding.

Full details of these courses, and of others being held in the latter part of 1959, can be obtained from the Secretary.

CONTRIBUTOR TO THE JOURNAL

K.H. McDowell, L.I.M., is Metallurgist in Charge at the Rodney Works of Bristol-Sidley Engines Ltd.

He was educated at St. George Grammar School, Bristol, and received his technical education at the College of Technology in the same City.

Mr. McDowell joined the Engine Division of the Bristol Aeroplane Co. Ltd. in 1935, and was transferred in 1940 to the Company's shadow factory at Accrington to become Production Metallurgist. He took up his present appointment in 1950.

BRANCH NEWS

Sessional Programmes

Eastern Counties

6th Oct.—Lecture on Stress Relieving by Dr. R. Weck (tentative). (Ipswich.)
27th Oct.—"*Welding and the draughtsman*" by H. B. Merriman. (Norwich.)
12th Nov.—Lecture on Fatigue in Welded Construction by Dr. R. Weck (tentative). (Colchester.)
8th Dec.—"*Welding and the draughtsman*" by H. B. Merriman. (Ipswich.)
12th Jan.—Film night. (Ipswich.)
23rd Feb.—To be arranged. (Norwich.)
25th Feb.—To be arranged. (Colchester.)
1st March—To be arranged. (Ipswich.)

East Midlands

13th Oct.—"*Some facts about iron powder electrodes*" by A. B. Fieldhouse. (Nottingham.)
17th Nov.—"*Heavy-gauge resistance welding in the aircraft industry*" by a representative of Sciaky Electric Welding Machines Ltd. (Derby.)
15th Dec.—"*Requirements and general aspects of manual arc-welding plant*" by R. H. Boughton. (Nottingham.)
10th Jan.—Paper on welding in BTC diesel development programme, by G. Walton. (Loughborough.)
2nd Feb.—"*Welding and the draughtsman*" by H. B. Merriman. (Nottingham.)
11th March—"*Effect of welding and stress relief on parent plate material*" by J. E. Roberts. (Lincoln.)
5th April—Annual General Meeting and Films. (Nottingham.)

All meetings will start at 7.15 p.m. Those at Nottingham will be held in the Victoria Station Hotel: at Derby in the College of Art; at Loughborough in the College; and at Lincoln in the Technical College.

East Wales

6th Oct.—"*Materials and fabrication problems in reactor technology*" by A. Prince. (Park Hotel, Park Place, Cardiff.)
4th Nov.—"*Locked-up stresses, distortion, and welding procedure*" by E. Flintham. (S.W. Institute of Engineers, Park Place, Cardiff.)
8th Dec.—"*Selection and use of arc-welding processes*" by E. Flintham. (Llandaff Technical College, Cardiff.)
12th Jan.—"*Welding and the draughtsman* by H. B. Merriman. (Education and Welfare Dept. of Richard Thomas & Baldwin Ltd., Ebbw Vale).
9th Feb. "*Argonarc welding of corrosion- and heat-resisting steels*" by J. A. McWilliam. (Park Hotel, Park Place, Cardiff.)
8th March—"*Inert-gas metal-arc welding of aluminium*" by A. R. Woodward and E. M. Wilson. (Llandaff Technical College, Cardiff.)

Meetings startat 7.0 p.m.

Leeds

22nd Sept. Ladies Night and Films.
7th Oct.—"*Quality welding*" by M. Birkhead.
27th Oct.—"*Modern fabrication methods in the shipbuilding industry*" by W. Mellanby.
17th Nov.—Brains Trust—Open Night.
10th Dec. Annual Dinner (Hotel Metropole, Leeds).
17th Dec.—"*The 250 ft diameter radio telescope at Jodrell Bank*" by C. N. Kington.
21st Jan.—"*Fabrication of the Bradwell heat exchangers*" by B. K. Twigg and A. R. Muir.
12th Feb. Dinner Dance (Mansion Hotel).
16th Feb.—Lecture by A. A. Smith of B.W.R.A.
16th March—Visit to Works of Joseph Rhodes (Wakefield).
12th April—Annual General Meeting.

Except where otherwise indicated, meetings will be held at the Great Northern Hotel, Leeds, starting at 7.30 p.m.

Liverpool

3rd Oct.—Visit to Works of Associated Ethyl, Ellesmere Port.
13th Oct.—"*Mastering imperfections by a code of good welding practice*" by C. Spencer. (Memorial Lecture to G. Gordon Musted.)
11th Nov.—"*Welding in warship construction*" by W. R. Seward. (Joint Meeting with Liverpool Metallurgical Society. Held at the International Library, William Brown Street, Liverpool 3.)
8th Dec.—"*Gas-shielded arc processes with consumable electrodes*" by D. B. Tait.
12th Jan.—"*Welding and physical metallurgy*" by T. Fullwood.
9th Feb.—"*The Runcorn/Widnes bridge project*" by J. K. Anderson.
8th March—"*Uses and welding of Hastelloy*" by R. Owen.
8th April—16th Annual Dinner to entertain the lecturers—St. George Restaurant, Liverpool.
12th April—Annual General Meeting and Film Show.

Except where otherwise indicated meetings are held at the College of Technology, Byrom Street, starting at 7.30 p.m.

N.E. Tees-side

21st Oct.—Lecture on welded structures.
18th Nov.—"CO_2 *welding of steel*" by G. Phipps.
16th Dec.—"*Some aspects of the changeover from riveting to welding in shipbuilding*" by C. W. Staincliffe.
20th Jan.—Open discussion.
17th Feb.—"*Manufacture and distribution of industrial gases*" by R. A. Exton.
16th March—"*Selection and use of arc-welding processes*" by E. Flintham.
13th April—Annual General Meeting and Chairman's Address.

Meetings are held at the Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, starting at 7.30 p.m.

North London

16th Sept.—Presidential Address by R. W. Ayers, and discussion.
21st Oct.—"*Welding of nickel and high-nickel alloys*" by J. Hinde.
18th Nov.—Demonstration of applications of stud welding by R. W. Taylor.
16th Dec.—Visit to Angel Road Works of British Oxygen Gases Ltd. for demonstrations of gas, metal-arc, shielded-arc welding processes and computor-controlled flame cutting.
20th Jan.—"*Further developments in the welding of atomic plant*" by A. Prince.
10th Feb.—Joint meeting with South London Branch.
16th March—"*Welding of low-alloy steels*" by J. F. Wilkinson.
20th April—Annual General Meeting.
21st April—(Tentative). Joint Annual Dinner with South London Branch at Connaught Rooms.

Meetings are held at 54 Princes Gate, London, S.W.7, starting at 7.30 p.m.

North London (Slough Section)

6th Oct.—"*Aluminium welding and cutting*" by J. E. Tomlinson.
8th Dec.—"*Low-temperature welding and brazing*
9th Feb.—"*Design for welding*" by F. Brooksbank.
5th April—"*Shop inspection of welds*".

Meetings are held at the Community Centre, Slough, at 7.0 p.m. for 7.30 p.m.

South London

7th Oct.—"*Selection of welding processes*" by B. K. Barber.
11th Nov.—"*Welding from the viewpoint of Lloyd's Register of Shipping*" by G. M. Boyd.
9th Dec.—"*Characteristics of welding plant*" by J. C. Needham.
13th Jan.—To be arranged.
10th Feb.—"*Construction of liquid methane cold storage plant*" by D. Slater and H. F. Goodman. (Joint meeting with North London Branch.)
9th March—"*Survey of welding development*" by A. A. Smith.
13th April—Annual General Meeting.

Meetings are held at 54 Princes Gate, London, S.W.7, starting at 7.30 p.m.

South London (Medway Section)

28th Oct.—"*Welding and the draughtsman*" by H. B. Merriman.
25th Nov.—Film and talk by W. Roy. (At Works of Frederick Braby & Co. Ltd.)
27th Jan.—Demonstrations of new welding processes. (At Medway Technical College, 2.0, 4.30, 6.30, and 9.0 p.m.)
23rd March—"*Developments in automatic welding with particular reference to the electro-slag process*" by A. M. Horsefield.
6th April—Annual General Meeting.

Except where otherwise indicated meetings are held at the Sun Hotel, Chatham, starting at 7.30 p.m.

South Western

6th Oct.—"*The 250 ft diameter radio telescope at Jodrell Bank*" by C. N. Kington. (Radiant House, Bristol, or the University.)
6th Nov.—Welding Forum. (Gloucester School of Technology.)
8th Dec.—To be arranged. (Radiant House, Bristol.)
12th Jan.—"*Welding in warship construction*" by Mr. Gundray. (Stothert & Pitt Ltd., Bath.)
9th Feb.—"*Functions of stress relieving*" by Dr. R. Weck. (Radiant House, Bristol.)
1st March—"*Welding and the draughstman*" by H. B. Merriman. (Bristol Aircraft Co. Ltd., Filton.)
29th March—"*Materials and fabrication problems in reactor technology*" by A. Prince. (Radiant House, Bristol.)
13th April—Annual General Meeting.

Meetings start at 7.15 p.m.

West of Scotland

21st Oct.—"*Welding of pressure pipework for high- and low-temperature operation*" by J. B. Marriott.
18th Nov.—"*Welding and testing of skirt supports for spherical pressure vessels*" by J. A. Forrest.
16th Dec.—"*Welding of rolling stock at British Railways*" by G. Walton.
20th Jan.—"*Photo-electric automatic flame-profiling*" by J. Marsh.
17th Feb.—"*Shipyard re-organization for welded construction*" by R. Straton.
16th March—"*Welding and the draughtsman*" by H. B. Merriman.
27th March—Visit to Works of British Hydrocarbon Chemicals Ltd., Grangemouth.
20th April—Annual General Meeting and Film Night.

All meetings start at 7-0 p.m. Except for the visit on 27th March, meetings will be held at the Institute of Engineers and Shipbuilders, Glasgow C.2.

West Wales

5th Oct.—"*Materials and fabrication problems in reactor technology*" by A. Prince. (Swansea Technical College.)
2nd Nov.—"*Class I fusion welded mild steel pressure vessels*" by A. H. Briscoe; and colour film "*Welding of high-pressure boilers*". (Swansea Technical College.)
7th Dec.—"*Selection and uses of arc-welding processes*" by E. Flintham. (Neath Technical College.)
11th Jan.—"*Welding and the draughtsman*" by H. B. Merriman. (Steel Company of Wales, Old General Office, Port Talbot.)
8th Feb.—"*Modernization of British Railways (Western Region)*" by M. G. R. Smith and R. A. Smeddle. (Swansea Technical College.)
7th March—"*Inert-gas metal-arc welding of aluminium*" by A. R. Woodward and E. M. Wilson. (Swansea Technical College.)

Meetings start at 7.0 p.m.

Preston **Southern Counties**

The programmes for these Branches were received too late for inclusion. They will be published in the October issue of the *Journal*.

BRITISH WELDING RESEARCH ASSOCIATION

Staff Changes

To increase the effectiveness of the contacts between the Association and its members and to facilitate the rapid application of research results, the functions of the Liaison and Publications Departments have now been combined under the direction of a new Members Service Department.

The Head of the new Department is Mr. P. H. R. Lane, B.Sc.(Eng.), who has been Deputy Chief Metallurgist of the Association. Mr. R. G. Burt, O.B.E., B.Sc. (Eng.), hitherto Chief Development Officer, will be remaining with the Association as Development Consultant. The editor for reports and publications, including the two cover-to-cover translations of Russian monthly welding journals, is Mr. L. Parkes, recently appointed to the staff of this Department. A Design Section is also to be set up to deal with members' problems in this field.

"Welding Production"

As announced in the June issue of the Journal, the Association is undertaking a second cover-to-cover translation from the Russian publication "*Svarochnoe Proizvodstvo*" (*Welding Production*) similar to the now well established translation "*Automatic Welding*".

Welding Production, in its original Russian form, is published in Moscow by Mashgiz. It deals mainly with welding equipment and practice in contrast to the emphasis on research in *Automatic Welding*. For the year 1959 it will be possible to translate and issue only the nine copies from April to December, and the subscription has been fixed at £4 or $11 for these issues (15*s*. or $2 for single issues).

The contents of current issues of both *Automatic Welding* and *Welding Production* are given each month in the Current Literature section of *BWJ*.

Subscriptions for either periodical should be sent to the British Welding Research Association, Abington Hall, near Cambridge, England.

INTERNATIONAL INSTITUTE OF WELDING

1959 Annual Assembly

The Twelfth Annual Assembly of the International Institute of Welding (I.I.W.) was held from 28th June to 4th July 1959 at Opatija, Yugoslavia, at the invitation of the Association of Welding Societies of Yugoslavia. Participants from twenty-three countries attended and numbered more than seven hundred (delegates, experts, observers, and those accompanying them).

The Assembly was opened by the Chairman of the Yugoslav Sponsoring Committee, Mr. Franc Leskošek, Vice-President of the Federal People's Assembly of Yugoslavia. Dr. U. Guerrera (Italy), President of the I.I.W., as well as Professor Ing. M. Radojković, Chairman of the Yugoslav Organizing Committee and Mr. Z. Sušanj, President of the People's Committee of Opatija, also spoke at the opening ceremony.

The programme of the Assembly included two meetings of the Governing Council, two meetings of the Executive Council, four meetings of each of the technical Commissions of the I.I.W., and a Public Session for the presentation of papers.

The Yugoslav Organizing Committee had the considerable task of preparing for the Assembly and ensuring that the arrangements were smoothly carried out. In addition to the technical and scientific programme, the Organizing Committee arranged for various social events, including a reception given for all participants by Mr. Leskošek on board M/S *Jugoslavija*. The opportunities thus provided for participants to meet each other socially contributed to the friendly atmosphere of the Assembly.

In the week following the Assembly, participants had the choice of taking part in three bus tours to different parts of Yugoslavia, lasting six to ten days and of industrial as well as scenic and historic interest.

Public Session

The Public Session held on Monday, 29th June, was presided over by Professor Ing. Milan Radojković, Vice-President of the I.I.W. and head of the Yugoslavian delegation on the Governing Council.

Forty-four papers from sixteen countries were printed and circulated to those attending the Assembly. They dealt with the theme of "Welding and Allied Processes in Main-

tenance and Repair Work" and were presented by the Yugoslavian rapporteurs in five groups:

(*a*) Study of techniques used in repair work
(*b*) Problems raised in repair work by the nature of the base and filler materials and by the properties to be obtained in service
(*c*) Typical examples of the repair of parts or the maintenance of equipment in particular industries
(*d*) Organization of maintenance and repair work in relation to the special needs of particular industries
(*e*) Economic questions relating to the use of welding and allied processes in maintenance and repair work.

The papers, the statements of the rapporteurs, and the lively discussion that followed the presentation will be published in a single volume.

Exhibition

As in previous years, an exhibition of publications dealing with welding and allied processes and of photographs of welded constructions was held during the Assembly.

A catalogue of the new publications shown at Opatija will be prepared for addition to the four catalogues dealing with previous exhibitions.

Elections

Mr. Walter Edström (Sweden) was elected to succeed Dr. U. Guerrera (Italy) as President in 1960.

Mr. Fernand Frenay (Belgium) was elected a Vice-President in succession to Mr. A. Robert Jenkins (U.K.).

Mr. A. Leroy (France) was re-elected Scientific and Technical Secretary.

The Energoinvest Laboratory, Sarajevo, Yugoslavia, was elected a new member of the I.I.W.

Work of the Commissions

The work carried out by the Commissions since the Assembly in Vienna last year will be described as usual in reports prepared by the respective chairmen. In addition, several documents have been recommended for publication, and these will appear later in the technical press.

One of these documents is the lecture, in memory of Professor E. Houdremont (Germany), delivered to Commission IX by Professor P. Bastien (France) on "Hydrogen in welding—a comparison between the behaviour of welded, cast, and wrought steels".

In addition, the Council have decided to publish the following separate documents:

"*Radiographs of Welds*"—a booklet containing prints of 26 characteristic radiographs from the "*Collection of Reference Radiographs of Welds*".

"*Concordance between the Universal Decimal Classification and the I.I.W. Classification System*"—a booklet resulting from the work of a joint committee of the I.I.W. Documentation Commission and the International Federation of Documentation. It will be published by the latter organization.

Several Commission documents will be transmitted as working documents to the International Standards Organization, and to the European Coal and Steel Community.

Publications

The publications mentioned in the foregoing can be obtained from the member societies of the I.I.W.

Earlier publications can also be obtained from the same sources. These include the quarterly Biolibgraphical Bulletin for Welding and Allied Processes; four sections of the Multilingual Collection of Terms for Welding and Allied Processes; the Collection of Reference Radiographs of Welds; a List of Terms used in Ultrasonic Testing; and the commemorative book "I.I.W./I.I.S. 1948–1958".

United Kingdom Delegation

The U.K. delegation of thirty-six, headed by Mr. A. Robert Jenkins, J.P., took an active part in the Assembly, being represented on all Commissions. Among the papers contributed to the Public Session, three were by U.K. authors; Mr. J. Barrington Stiles on "Metal Spraying", the late Mr. Gordon Musted on "Reclamation of a 30-ton Steel Casting by Welding", and Mr. S. Wise on the "Strength of Components Repaired by Welding".

British publications formed an impressive part of the exhibition of publications and photographs.

At this Assembly Mr. Jenkins retired from the Vice-Presidency at the end of three years' term of office. He will continue to represent the U.K. on the Governing Council, together with Dr. R. Weck, Director of the British Welding Research Association, and Mr. Guy Parsloe, Secretary of the Institute of Welding, who is also Secretary-General of the I.I.W.

Dr. Weck is Chairman of the Commission on Residual Stresses and Stress Relieving, while Dr. H. G. Taylor, Director of the British Electrical Research Association, presides over that on Resistance Welding. Mr. E. Seymour-Semper, President of the Institute of Welding, is the U.K. Delegate on the Gas Welding Commission.

PUBLICATIONS

Brazing Graphite to Nilo-K Tubes

A brief report, describing the technique of brazing graphite to metal carrier tubes, has been prepared by B. Stapleton of the Research and Development Branch of the U.K.A.E.A. Industrial Group at Capenhurst.

It gives details of the apparatus used, the preparation of the specimens, the operation of a vacuum furnace, and the testing of the resulting joints.

The author concludes that satisfactory leak-tight joints can be made by the maintenance of a high vacuum at the braze, and scrupulous cleanliness of all the components before brazing. The materials must be hot degassed before brazing.

Copies of the report, I.G. 140 (RD/CA) may be obtained from H.M. Stationery Office, price 2*s.* 6*d.*

CORRECTION

In the July issue of the *Journal* (p. 311) a line has been misplaced. The whole line directly above the illustration of the Hancomatic profiling machine should be transposed to the foot of the same column. We apologize to the British Oxygen Company and to Hancock & Co. for the confusion that has arisen from this error.

DIARY

2nd Sept.—North Eastern (Tees-side)—Visit to Lackenby Works of Dorman Long & Co. Ltd., 7.30 p.m.

16th Sept.—East of Scotland—Chairman's Address by J. F. Wheeldon (25 Charlotte Square, Edinburgh 2, 7.30 p.m.)
North London—Presidential Address and Discussion (54 Princes Gate, 7.30 p.m.)

22nd Sept.—Leeds—Ladies Night and Travel Films (Great Northern Hotel, Leeds, 7.30 p.m.)

1st Oct.—North Eastern (Tyneside)—Chairman's Address by R. A. Exton (Mining Institute, Neville Hall, Newcastle, 7.0 p.m.)

5th Oct.—West Wales—"*Materials and Fabrication Problems in Reactor Technology*" by A. Prince (Swansea Technical College, 7.0 p.m.)

6th Oct.—East Wales—Repeat of West Wales lecture (Park Hotel, Park Place, Cardiff, 7.0 p.m).
South Western—"*The 250 ft diameter Radio Telescope at Jodrell Bank*" by C. N. Kington (Radiant House, Bristol, or the University, 7.15 p.m.)
North London (Slough Section)—"*Aluminium Welding and Cutting*" by J. E. Tomlinson, (Community Centre, Slough, 7.30 p.m.)
Eastern Counties—Lecture on Stress Relieving by Dr. R. Weck (Ipswich—to be confirmed).

7th Oct.—East of Scotland—Visit to Works of Pressed Steel Co. Ltd., Paisley, 7.0 p.m.

Manchester—"*The Importance of Welding Research for Industry*" by Dr. R. Weck (College of Technology, 7.15 p.m.)
South London—"*Selection of Welding Processes*" by B. K. Barber (54 Princes Gate, 7.30 p.m.)

APPOINTMENTS

Situations Vacant

City company require expert welding engineer for marketing and sale of new type welding machine. Box. No. 233.

Situations Wanted

Advertiser desires change. At present in charge of Small Engineering Shop in East Midlands. More interested in Heavy Welding than administration. 22 years' experience in Welded Fabrications; passed all tests – A.I.D. Lloyd's, etc. Anything considered. Box. No, 234.

The cost of insertions in this column is 3*s.* 6*d.* a line, or 30*s.* per inch depth semi-display.

Box numbers are added for the additional charge of 2*s.* 6*d.* Replies should be addressed to Box. —, Institute of Welding, 54 Princes Gate, London, S.W.7.

All other matters relating to advertisements for this section of the News should be addressed to the Executive Editor, 6 Ridge End, Hook Hill Lane, Woking, Surrey (Tel. Woking 2981).

Copy should be sent by 6th of each month for publication in the following month.

Current WELDING LITERATURE

Book Reviews

Additions to the Institute Library

Trade Publications

CONTENTS OF PERIODICALS RECEIVED

This section is intended to give a survey of the current welding literature received by the Institute of Welding Library. The contents lists are not exhaustive; only the main articles in welding journals are listed, and reprints from other journals and short notes are generally excluded. In addition, welding articles from other periodicals are listed. Abstracts of welding literature are given in the Bibliographical Bulletin of Welding and Allied Processes, *published by the International Institute of Welding, and details of this may be obtained from the Secretary of the Institute of Welding.*

Welding Journals

Australian Welding Journal, 1959, vol. 2, No. 6, February

Submerged arc welding of pressure pipes, N. H. Booth (6–12)

A stainless clad steel weldment, J. R. Robinson (13–14)

Design and automatic welding of brewery vessels; the first automatically welded stainless steel-clad vessels, G. F. Sanderson (21–25)

Production "hidden arc" welding, A. J. Hundt (26–27)

Automatic Welding (U.S.S.R., translated by the B.W.R.A.), 1959, April

Anchoring tubular lattice members to gusset junction plates, V. I. Novikov, V. A. Kovtunenko and O. I. Shumitskii

Selection of fillet weld type and dimensions for T-joints, A. A. Kazimirov

Certain relationships between weld pool shape and welding conditions in electro-slag welding, S. A. Ostrovskaya

Welding of clad 12MKh 08Kh12 (EI 496) metal, I. N. Gerasimenko

Ageing of welds in two-phase alloys of titanium with aluminium and vanadium, S. M. Gurevich and V. F. Grabin

Resistance of submerged-arc welds to porosity caused by rust, using ceramic fluxes, D. M. Kushnerev

Development of a technique for electro-slag welding of boiler shells made of type AK medium alloy steel, A. M. Makara, I. V. Novikov, V. A. Lutsyuk, G. V. Nazarov and V. I. Ryabinkin

Cold upset butt welding of copper trolley wires, I. B. Baranov

Electro-slag remelting of steel at the "Dneprospetstal" works, A. F. Tregubenko and V. G. Speranskii

Arc welding of copper and copper-nickel alloys to steel, A. E. Vainerman

Use of resistance strain gauges to measure compressive stresses in spot-welded components, M. D. Rudman

A new possible use of IG-2 generators for spectrographic analysis of high-alloy steels and welds, A. S. Demyanchuk, V. M. Plotnitskii and O. P. Ryabushko

Co-ordination of Scientific Research on Welding

Scientific Council of the E. O. Paton Institute, I. I. Zaruba

Conference of readers of *Automatic Welding*, M. Zilbman

Automatic Welding (U.S.S.R., translated by the B.W.R.A.), 1959, May

Properties and weldability of steel type M in thicknesses from 70 to 160 mm, S. A. Ostrovskaya

High strength welds in the automatic CO_2 welding of 30KhGSA steel, N. I. Kakhovskii

Some features of droplet transfer from heavy electrodes in electro-slag welding, D. A. Dudko, I. N. Rublevskii, and G. S. Tyagun-Belous

Frequency changer for resistance welding, N. V. Podola

Low-alloy silicon-manganese steels for welded building structures, A. Ya. Brodskii

Physico-chemical investigation of the modification of sigma-phase in austenitic-ferritic deposited metal, N. Ya. Karasik and H. E. Shlepyanova

Procedure for etching and for preparing carbon replicas of welds in titanium and in aluminium, V. F. Grabin

High brittleness in 28% Cr–10% Ni stainless steel, V. I. Dyatlov and N. I. Kopersak

Low-voltage self-excited d.c. generators for fine-wire CO_2 welding, A. G. Potapevskii and V. G. Mechev

Standardization of the procedure for short welds, D. K. Bezbak

Fatigue strength of the low-alloy steels 14G and 19G, A. A. Bat

Training of welding teams, A. G. Galaktionov

Conference on Welding

Wagon Building Conference, G. O. Olifer and M. G. Zilban

At the E.O. Paton Arc Welding Institute

At the Kiev Polytechnic Institute, M. N. Gapchenko

Canadian Welder, 1959, vol. 50, March

World's largest welding boom, F. C. Livingstone (10–12)

"Fusarc/CO_2" process being introduced to Canada (14–15)

Resistance welding in appliance manufacture (16–17)

Canadian Welder, 1959, vol. 50, April

Airco's new "Dip transfer" welding process (18–20)

Industry and Welding (U.S.A.), 1959, vol. 32, March

How to weld 2 7/8 in. thick stainless-clad Mn–Mo steel (27)

High-speed fabrication of 120 ft girders (28–30)

Automatic welds spheres from the inside (31, 65)

Two stage multi-spot welder makes 260 auto-frame sub-assemblies an hour (35, 60)

Automatic fixturing is the key to precision welding and soldering (36–37, 60)

Semi-automatic welding of heavy fan casings is 25% faster, C. Burrow (38)

Report on non-destructive testing of welded fabrications (41–44, 47–48, 51–52, 55–57)

Non-destructive testing: how industry uses it (58–59)

Two-quality control procedures identify stainless wires, H. F. Reid (62–63, 65)

Tong tester gives instant checks on welding current (64–65)

Industry and Welding (U.S.A.), 1959, vol. 32, April

Welding distortion: what causes it and how to cure it, L. J. Larson (35–36, 67)

700 kVA machine fabricates 10 tons of grating in 8 hours (37, 95–96)

Ultrasonic welding: theory and practice, J. R. Wirt (38–39)

Automatic equipment speeds welding, eliminates rejects (40, 67)

Is laminated steel your problem? J. M. St. John (45, 96)

Highway guard rails are designed for welded fabrication (46–47)

Skip burning controls distortion, C. F. Brown (48)

Deposit hard facing three times faster with a semi-automatic (51, 96)

Redesign for welding speeds fabrication of 180 ton slab pusher (52)

Industry and Welding (U.S.A.), 1959, vol. 32, May

Economics in designing and manufacturing of welded fabrication. Part 1: Manufacturing: materials and methods, J. Mikulak (28–30)

Inert arc spot welding cuts costs 60% (31)

Trepan joint and low ferrite overlay stop fissuring, E. W. Rowlands (32–34, 46)

Check lists for tungsten inert arc welding, F. Kuncz (35)

High temperature brazing of turbojet components (36–37)

Penetrameters: sensitivity gauges for weld radiography, A. Greene (48, 50–51)

Journal of the Japan Welding Society, 1959, vol. 28, March

Safety and health aspects of gas and fumes in arc welding, part 1, H. Suemitsu (5–10)

Journal of the Japan Welding Society, 1959, vol. 28, April

Safety and health aspects of gas and fumes in arc welding, part 2, H. Suemitsu (3–8)

Crack test of mild steel electrode with cylinder type specimens, S. Ando and others (9–16)

A study of the modified Murex hot-crack testing method, part 1, K. Nakane and others (17–23)

Welding conditions of steels and cooling time near the fusion zone, parts 6 and 7, M. Inagaki (24–37)

Characteristics of the consumptions of anode and cathode in the tungsten arc, M. Ozawa and others (38–42)

A study of the mash seam welding of stainless steel, T. Nakamura and E. Maeda (43–48)

On the carbon dioxide-Sekiguchi's filler wire-arc welding process, part 13, H. Sekiguchi and I. Masumoto (49–54)

Journal of the Society of Naval Architects of Japan, 1959, vol. 104, January

Influence of weld faults on mechanical strength of welds, M. Watanabe and others (177–190)

External constraint and shrinkage of butt-welded joints in the erection of assemblies on the building way, M. Watanabe and others (191–200)

Root cracking in one side full penetration welding, T. Yoshida and others (227–236)

Theoretical research on the propagation of brittle fracture, Y. Akita (237–242)

Explosion tests on arc welded tubes with various welding procedures, H. Kihara and others (243–254)

Some experiments on the low temperature brittleness of steels, S. Abe (255–266)

On the pressed-notch Charpy test, F. Koshiga (267–274)

Restraint and residual stress in the construction of the middle class cargo-boat by a butt welding method, T. Kuniyasi and others (275–290)

Lastechniek (Holland), 1959, vol. 25, May

Recommendations for the choice and classification of steels for use in welded structures (IIW/IIS Comm. IX.–22–59) (108–110)

Przeglad Spawalnictwa (Poland), 1959, April

New conception of brittle fracture temperature determination for structural steel, T. Pelczynski

Analysis of rules for hull steel, S. Butnicki

On rupture theory, M. Zakrzewski

Fillet welds economy in ship construction in the light of classification codes, A. Piszcz

Welding technology of a tank for liquid fuels storage, A. Wiejski

Przeglad Spawalnictwa (Poland), 1959, May

New alloys for spot welding electrodes, part 1, Z. Misiolek and others

Production development of home-made welding equipment, R. Korkiewicz

Semi-automatic CO_2 shielded welding, B. Pierozek

Fabrication procedure of heavy power gearing casings, W. Patuchowski

Schweissen und Schneiden (Germany), 1959, vol. 11, April

The effect of moisture absorption and its delay with basic electrodes, E. Kauhausen and S. Sadowski (115–120)

The most important faults met with in oxy-acetylene fusion welding, H. Ehrenberg and H. Schmidt (121–126)

Membrane vibrations in welded structures, F. Eisele and H. Drumm (126–130)

Schweissen und Schneiden (Germany), 1959, vol. 11, May

New considerations for the welding and design of boiler components, W. Müller (159–171)

Hole piercing in steel by means of the oxy-acetylene cutting blowpipe, E. Zorn (171–5)

Comparative investigations into the bond strength of steel brazed with flux covered brass, J. Colbus (175–8)

Welding under piecework conditions, G. Becher (179–184)

Schweisstechnik (Germany), 1959, vol. 9, May

International relations with regard to welding practice, A. Neumann (145–6)

Some prospects and tasks concerning welding and brazing of non-ferrous metals, E. Lüder (147–9)

On the brittle fracture behaviour of carbon steel welds with decomposition zones, part 2, F. Erdmann-Jesnitzer (149–153)

Fatigue strength and filler metal, R. Rieger and G. Becker (154–5)

Formation of flaws in the weld metal of plain structural steels under endurance tensile-load, F. Erdmann-Jesnitzer, G. Hötsch, S. Müller (156–159)

Viscosity measurements on weld slags, W. Höhn (160–3)

Investigations of the production of cracked gas of low-grade oils by means of short-time arcs for gas welding, G. Tybus (164–8)

Welded design in building- and bridge-steel constructions, K. Latzin (169–174)

Soudage et Techniques Connexes (France), 1959, vol. 13, January–February

On the weldability of various carbon or alloy steels, P. Bastien, Ch. Dubois, H. Lejay and C. Roques (5–30)

The practical application of the standardized image quality indicator used for radiographic purposes (33–42)

Welding of nickel and high-nickel alloys in the chemical industry, J. Hinde (43–51)

The steelwork of the French Pavilion at the International Exhibition, Brussels, J. Corpelet (61–67)

Soudage et Techniques Connexes (France), 1959, vol. 13, March–April

Comments on the latest developments of arc welding processes, A. Gaubert (85–98)

IIW. Commission IX. Recommendations for the choice and classification of steels for use in welded structures (99–102)

Development of a transition weld between ferritic and austenitic superheater tubing for steam plant application, B. Lofblad and G. Lindh (103–111)

IIW. Commission I. General recommendations for oxygen cutting of mild and low alloy steels (113)

Dynamic behaviour of D.C. generators for arc welding. Proposal for a definition of "suitability for welding", by A. Carrer (114–123)

Recent achievements in automobile body welding, J. Vandamme and J. Peronnin (127–136)

IIW. Commission V. Use of calibration blocks for the control of ultrasonic testing equipment (149–157)

South African Institution of Welding, 1959, Bulletin No. 73, April

Classification of mild steel metal arc welding electrodes (2–5)

Welding training (5–8)

Welding Engineer (U.S.A.), 1959, vol. 44, May

A welding and pipelining history (33)

Hardfacing drill bits—another contribution to the oil industry (35–36)

Fabricating a water softener by welding (38–39)

Another firm (High Vacuum Equipment Corporation) offers electron-beam welder to industry (40–42)

New systems eliminates CO_2 disadvantages (46)

Ultrasounds in use to improve normal welding (48–49)

For Mig welding, extruded uranium welding wire proves best, E. G. Brundige and J. M. Taub (58)

Welding Journal (U.S.A.), 1959, vol. 38, May

Welding of containment sphere for Dresden Nuclear Power station, P. C. Arnold (461–469)

Oxyacetylene pressure welding of high speed rocket test track, E. S. McKittrick and W. E. Donalds (469–474)

Roll spot welding for ballistic missiles, J. K. Dawson (475–479)

Alloy steels for big shovel welding by semi-automatic submerged arc, A. Tozer (480–481)

Welded design leads to low-cost structural steel parking deck (482–483)

Magnetic-flux gas-shielded welding 3 to 1, C. F. Crowson (489)

Normalization procedures for NRL drop-weight test, P. P. Puzak and A. J. Babeck (209s–218s)

Spot welding of titanium alloys, R. K. Nolen, J. F. Rudy H. Schwartzbart and H. D. Kessler (219s–221s)

Welding of medium-alloy chrome-moly steels, K. R. Notvest (222s–227s)

Welding properties of chromium-nickel-molybdenum hardenable stainless steels, R. H. Kaltenhauser (228s–231s)

Filler wire for welding army ordnance armor, S. M. Silverstein, R. P. Sopher and P. J. Rieppel (232s–240s)

Welding News (Australia), 1959, Folio 97, January

Argonarc at Qantas (2–3)

Argonarc welding of stainless steel (8–9)

Cut those costs (15–18)

Flame hardening (22–23)

Welding News (Holland), 1959, No. 98, February

Copper block welding of rails in Great Britain, E. J. Rogers (2–7)

Automatic welding of thin sheet steel in the Netherlands, R. Boekholt (8–13)

Welding News (Holland), 1959, No. 99, March

Welding chassis sidemembers at John Thompson Ltd. The method and equipment using fully automatic bare-wire CO_2-welding process, S. Astley

Welding Production (U.S.S.R.), translated by the B.W.R.A.) 1959, May

Gas cutting and welding: 1959 to 1965, A. N. Shashkov.

Techniques for welding the reactive metals, A. W. Mordvintseva and N. A. Olshanksky

Study of CO_2 shielded weld deposits, using Sv–08GSA and Sv–08G2SA electrode wire, A. M. Novozhilov and A. M. Sokolova

Sulphur content: its effect on porosity in automatic submerged-arc welds, L. S. Sapiro

Distribution of heat flow between the plates in an arc-welded tee-joint, G. A. Belchuk

Static characteristics of the under-water welding arc, T. I. Avilov

Physics and chemistry of metal spraying, A. F. Krupin

Flash welding of heat-resistant austenic steel tubes, E. S. Shepak and A. S. Gelman

Equipment for mechanizing the assembly for circumferential welds in pressure vessels, A. G. Fomin

Repair of crane wheels by hard facing, M. A. Tylkin, V. M. Sivak, I. F. Parfentiev, and M. A. Kropp

Powder cutting of stainless steels in shipbuilding, B. I. Smirnov

Nitrogen-arc cutting of stainless steels, I. S. Shapiro

Economy of acetylene in steel cutting, M. S. Kerner

Hard facing for rock breakers and other plant, M. A. Tylkin

Control of cracking in fillet welds on low-alloy steels, G. V. Nazarov

Straightening of welded components by local heating, L. D. Veretnik

Electrode holder BE3–250 for welding without stub ends, S. I. Kirichenko and M. L. Fukelman

Results of the 1958 All-Union Competition organized by NTO MashPROM for the advancement of welding practice, V. M. Kondratovich

Organization of the Central Welding Laboratory in the Kaliningrad District, B. V. Azarov

Conference of readers of Svarochnoe Proizvodstvo, P. N. Berezkin and G. D. Shvartsburd

Recent Soviet welding articles, titles and authors

Welding Research Abroad (U.S.A.), 1959, vol. 5, April

IIW/IIS Behaviour of metals subjected to welding (Comm. IX), (29–33)

IIW/IIS Recommended practices for flash welding of hard steels (Comm. IIIc–89a-58), (34–37)

IIW/IIS Bibliography of resistance welding of dissimilar metals (Comm. III–74–57), (38–46)

IIW/IIS Special arc welding processes (Comm. XII), (46–48)

IIW/IIS Stress relief of 1% Cr, 0·5% Mo Steel (Comm. X–189–58), (54–62)

IIW/IIS Welding Instruction (Comm. XIV). (63–64)

Welding Research Abroad (U.S.A.), 1959, vol. 5, May

Fatigue strength of steel plates with welded-on inserts, I. V. Kudryavtsev and N. A. Balabanov; translated from *Svarochnoe Proiz.*, 1956, June, pp. 1–5 (27–42)

Zvaranie (Czechoslovakia), 1959, vol. 8, April

Steel oxy-cutting in die forging shops, J. Bezdicek and J. Zabrodsky (97–100)

Contribution to the estimating of electrode capacity, J. Vidrma (101–104)

Manual arc spot welder ROB 3, L. Müncner (104–107)

Problems of surfacing in metallurgical service and the production of endless tubular electrodes, B. Kalita (108–110)

Shaping of welding surfaces of heavy aluminium plate and sheet sections, J. Svejda (110–115)

Flux cleaning, R. Solc (116)

Zvaranie (Czechoslovakia), 1959, vol. 8, May

Metal brazing: examples of brazed joint structures, P. Slysko (130–136)

Electro slagwelding in boiler drum construction, O. Hajzler (136–140)

Welding of grey cast iron in the Rumanian People's Republic, T. Salagean (140–142)

First step to typifying suspendable welding tongs, L. Pliva (142–148)

Metal powders for electrode coating, F. Zahoransky (149–152)

How to improve working conditions in the welding shop, J. Vodera (153–155)

Other Journals

Brazed steel honeycomb structures for 800 F, C. F. Burrows (*Materials in Design Engineering*), (U.S.A.), 1959, vol. 49, April, pp. 110–112)

Cast iron welding, K. Fairweather (*New Zealand Engineering*, 1959, vol. 14, March, pp. 95–98)

Weldability of high-strength steel, E. F. Nippes (*Metal Progress* (U.S.A.), 1959, vol. 75, April, pp. 128, 130, 132, 134–135)

Welding titanium for missiles, C. W. Handova (*Sheet Metal Industries*, 1959, vol. 36, May, pp. 359–360)

Brittle fracture in welded ships; an empirical approach from recent experience, J. Hodgson and G. M. Boyd (*Quarterly Transactions of the Institution of Naval Architects*, 1958, vol. 100, No. 3, July, pp. 141–180)

Large pipeline projects, A. C. Hartley (*British Petroleum Equipment News*, 1959, vol. 7, No. 2, Spring, pp. 98–103)

Nickel-containing steels for low-temperature applications in the petroleum industry, E. T. Gill (*British Petroleum Equipment News*, 1959, vol. 7, No. 2, Spring, pp. 60–64)

Plug welds cut costs and effort (*The Iron Age* (U.S.A.), 1959, vol. 183, April 9, p. 103)

The collapse of triangulated trusses by buckling within the plane of the truss, J. G. Nutt (*The Structural Engineer*, 1959, vol. 37, May, pp. 141–149)

The production, fabrication, properties and uses of some of the newer metals, N. P. Inglis (*The Journal of the Institution of Production Engineers*, 1959, vol. 38, May, pp. 219–244)

Yield point and high-temperature proof stress of carbon-manganese steel, J. Glen (*Journal of the West of Scotland Iron and Steel Institute*, 1957–8, vol. 65, pp. 141–191)

The argon-arc cutting process, P. G. Weeber and J. Hoven (*Smit Mededelingen* (The Netherlands), 1959, vol. 14, January to March, pp. 18–26)

Brazing under an electric blanket, D. E. Wernz and M. Schwartz (*Metal Progress* (U.S.A.), 1959, vol. 75, May, 109–112)

Probing for faults with ultrasonics (*Metalworking Production*, 1959, vol. 103, May 15, pp. 864–866)

Welding titanium; methods used for successful fusion and resistance welding (*Metal Industry*, 1959, vol. 94, 8 May, p. 371–4)

Progress in the development and application of steel plates, W. Barr (*Iron and Steel*, 1959, vol. 22, No. 6, June, pp. 219–223)

Two new superalloys for high temperatures (*Materials in Design Engineering* (U.S.A.), 1959, vol. 49, May. pp. 150–1)

Chapelcross: Britian's second full-scale nuclear power Station opened near Annan, Dumfriesshire (*Nuclear Engineering*, 1959, vol. 4, June, pp. 250–2)

Fuel elements for Dresden (U.S.A.), G. N. Spalaris (*Nuclear Engineering*, 1959, vol. 4, June, pp. 253–8)

Honeycomb structures; Martin practice in core manufacture and sandwich assembly, L. E. Laux (*Aircraft Production*, 1959, vol. 21, June, pp. 215–221)

Floating roof petrol tank, A. F. Butters (*Engineer and Foundryman* (South Africa), 1959, vol. 24, April, p. 43–47)

Design of steel structures by plastic theory, P. C. Varghese (*Journal of the Institution of Engineers* (India), vol. 39, no. 8, part 1, April 1959, pp. 817–842)

Electron beams—new technique for welding, G. Burton and R. L. Matchett (*Metalworking Production*, 1959, vol. 103, May 22, pp. 901–3)

Electro-slag welding comes to U.K. (*Metalworking Production*, 1959, vol. 103, No. 22, May 29, pp. 950–954)

High frequency metallizing, A. P. Vlasov (*Metal Industry*, 1959, vol. 94, 15 May, pp. 391–393)

Low temperature stress relieving of welded platework, J. C. Dixon (*Engineering*, 1959, vol. 187, 15 May, pp. 651–652)

Stress-relieving titanium alloy weldments, R. P. Brody and A. A. Taylor (*Metal Progress* (U.S.A.), 1959, vol. 75, May, pp. 67–71)

Welding electrode with built-in kinks, T. W. Shearer (*Metal Progress* (U.S.A.), 1959, vol. 75, May, pp. 95)

BOOKS AND PAMPHLETS

BRITISH STANDARDS INSTITUTION. BS.350:Part 1:1959. *Conversion factors and tables. Part 1. Basis of tables. Conversion factors.* (Price 15*s*)

BS.1295:1959. *Tests for use in the training of welders. Manual metal-arc and oxy-acetylene welding of mild steel.* (Price 10*s*)

BS.1547:1959. *Flameproof industrial clothing (materials and design).* (Price 3*s*)

BS.3082:Part 1:1959. *Mechanical testing of steel at elevated temperatures. Part 1. Determination of proof stress.* (Price 3*s*)

BS.499:1952. *Supplement No. 1* (1959). *Types of joints, welds, and preparations.* (Price 4*s* 6*d*)

BS.1870:Part 2:1959. *Safety footwear. Part 2. Rubber safety boots.* (Price 4*s*)

BS.3119:1959. *Method of test for flameproof materials.* (Price 3*s*)

BS.3120:1959. *Performance requirements of materials for flameproof clothing.* (Price 3*s*)

AMERICAN SOCIETY OF MECHANICAL ENGINEERS. *Boiler and pressure vessel code. Section VII; Suggested rules for care of power boilers.* 1959 ed. New York, A.S.M.E., 1959. (Price 30*s* 11*d*)

AMERICAN SOCIETY FOR METALS AND NEW MEXICO UNIVERSITY. *Metals for supersonic aircraft.* Proceedings of the Conference Heat tolerant metals for aerodynamic applications, held January 28 and 29, 1957, edited by D. W. Grobecker. Cleveland, A.S.M., 1958. (Price 62*s*)

BEEDLE, LYNN S. *Plastic design of steel frames.* New York, Wiley & Sons; London, Chapman & Hall, 1958. (Price £5 4*s*)

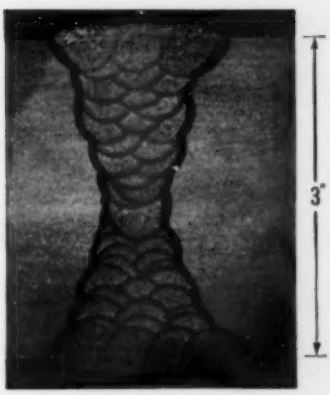
BRITISH ALUMINIUM COMPANY LIMITED. *Self-adjusting arc welding of aluminium and its alloys.* London, B.A.C. Ltd., 1959. (Publication No. L.8.5m.4/59)

BRITISH IRON AND STEEL FEDERATION. *Annual report*, 1958. London, B.I.S.F., April 1959.

Murex "Muraflux A" submerged-arc welding flux

High quality is essential in the weld metal of thick plate for nuclear power vessels and similar applications. This high quality can now be obtained by automatic methods using the new "Muraflux A" granular flux and the submerged-arc process. Excellent Charpy impact results at sub-zero temperatures and good elongation figures in welds in 3 inch thick steel plate can be produced by using "Muraflux A" with Murex "Murawire W2." The ultimate tensile strength of the weld metal matches that of the parent plate and its radiographic quality is sound.

This high quality can be combined with high production speeds when the new Murex "Muramatic" automatic welding equipment is used. In short, Murex "Muraflux A" granular flux, "Murawire W2" filler wire and the "Muramatic" machine provide a complete service for the automatic welding of thick plate by the submerged-arc process. Please write for full details.



MUREX

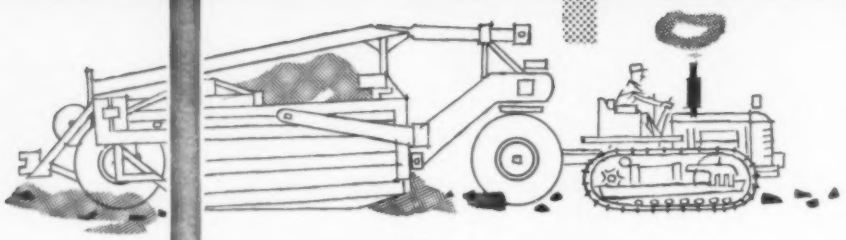
A complete service for automatic welding

MUREX WELDING PROCESSES LTD. WALTHAM CROSS, HERTS.

T 34

The INVICTA range of Electrodes covers *all* arc welding applications, and is in world-wide service throughout the shipbuilding and engineering industries. By choosing a specifically designed INVICTA Electrode, you can be sure of a perfect arc welding job every time

service to industry



'GENWAY' ELECTRODES

High quality, general purpose Electrodes for welding in all positions. Easy manipulation on wide range of joints. Readily removable slag from fillet welds exposes perfectly clean weld metal free from undercut.

'SPEEDWAY' ELECTRODES

Most economical due to fast running at comparatively low currents with very good penetration. Excellent for general engineering work, simple operation and easy slag removal.

APPROVALS

The Admiralty (all gauges mild steel).
Ministry of Transport.
Lloyd's Register of Shipping (United with British Corporation Register).
Complies with B.S.S.639/1952.

NORWEGIAN

Det Norske Veritas—all positions.
Also for welding 'W' and 'WW' quality steels.

INVICTA electrodes

Full details gladly sent on request.

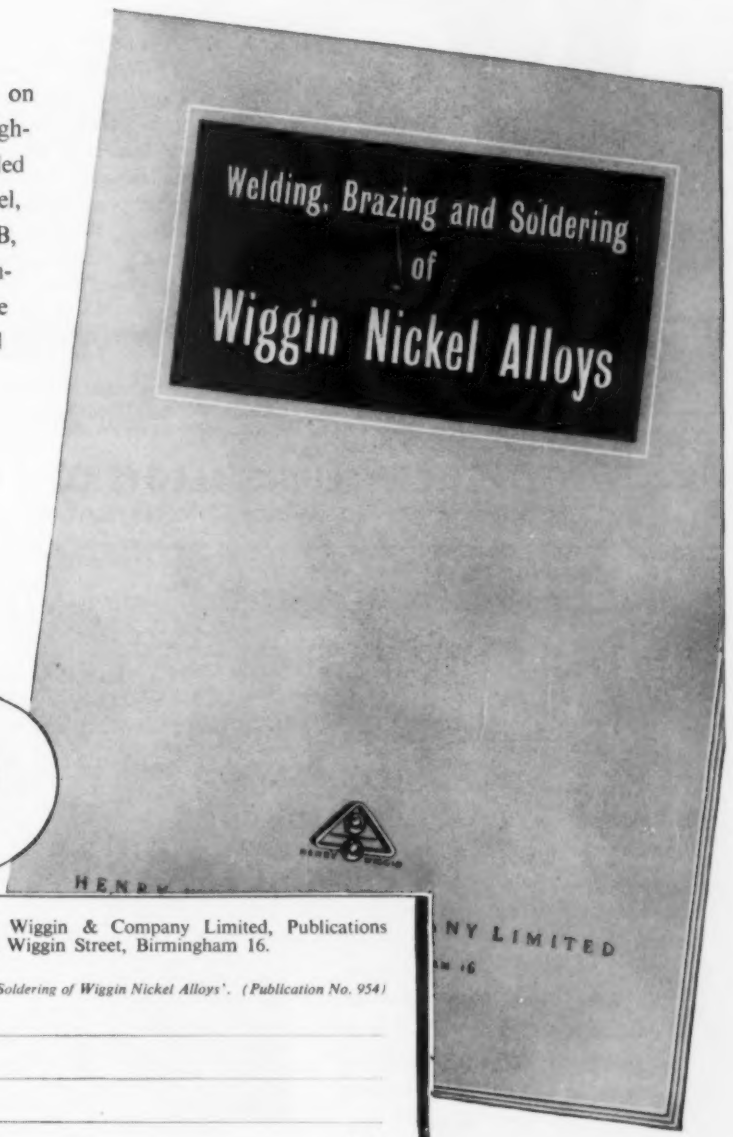
INVICTA ELECTRODES LTD.

Member of the Owen Organisation

BILSTON LANE WILLENHALL, STAFFS.
Telephone: James Bridge 3131. Extension: 308.

This new Booklet...

. . . gives full information on methods of joining Wiggin high-nickel alloys. It includes detailed recommendations for Monel, nickel, Inconel, Corronel B, the Nimonic series of high-temperature alloys and the Brightray series of electrical resistance materials.



Copies will gladly be sent on request

To: Henry Wiggin & Company Limited, Publications Department, Wiggin Street, Birmingham 16.

Please send me a copy of 'Welding, Brazing and Soldering of Wiggin Nickel Alloys'. (Publication No. 954)

Name _____

Appointment or department _____

Company _____

B.W.

HENRY WIGGIN & COMPANY LIMITED *WIGGIN STREET · BIRMINGHAM 16*

Registered T.M. applied for.

Meet 'LITTLE HUGH-TEC'

This engaging new figure in the welding world was created by world-famous poster artist SAVIGNAC to symbolize how industry can REPAIR WELD—SAVE MORE with 'Eutectic Low Temperature Welding Alloys'. He will appear on packs and printed matter the world over as a reminder of Eutectic's unique 'Low Heat Input' process for joining all metals.

The whole concept of 'Low Heat Input' welding, pioneered and developed by the Company over 50 years is based on the phenomenon of surface alloying first discovered by the Company's founder, J. P. H. Wasserman. Today, through the use of alloys and techniques exclusive to Eutectic, you can bond metals below the critical heat range, minimizing the cracking, distortion and embrittlement associated with high heat methods.

First applied to gas rods, the benefits of 'Low Heat Input' have been brought to a unique range of specially formulated alloys in paste, flux coated rod and electrode form for joining and overlaying applications.

Eutectic/Castolin research centres in U.S.A. and Switzerland are constantly improving on this impressive range. Plants in New York, Lausanne, London, Paris, Frankfurt, Brussels, Vienna, Montreal, Sao Paulo, and Mexico City. Repair Weld—Save More Sales and Service in 67 countries.

REPAIR WELD—SAVE MORE

FREE Send now for literature giving fuller information

SEE for yourself! Ask for our local Technical Consultant to give you a free demonstration and Weld Savings Report.

☐ PLEASE SEND Free literature and data

☐ Technical Consultant for demonstration.

NAME .....

BUSINESS ADDRESS .....

B.W.J.9.A

Low Temperature EUTECTIC WELDING ALLOYS

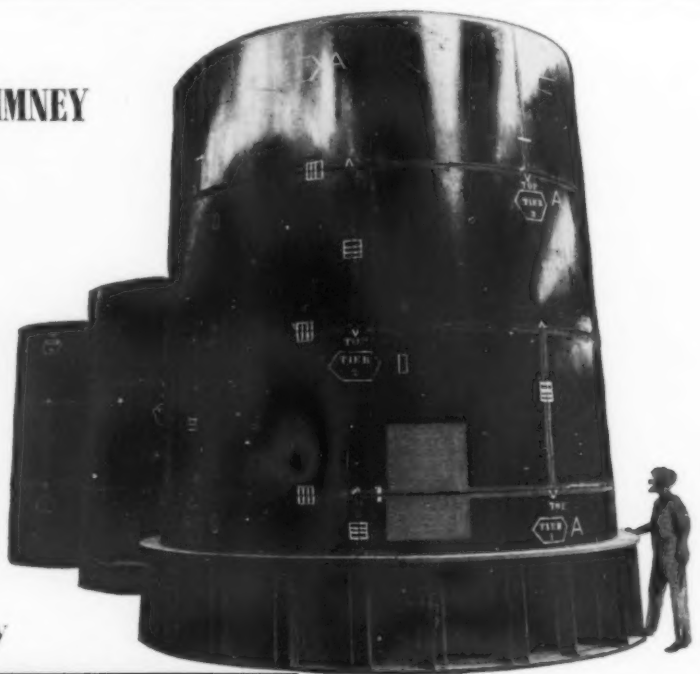
Trade Mark

EUTECTIC WELDING ALLOYS CO. LTD.

NORTH FELTHAM TRADING ESTATE · FELTHAM · MIDDX · Phone: FELtham 6571

150 ft. HIGH STEEL CHIMNEY for South America

To Venezuela BOOTHS of BOLTON have recently shipped a 150 ft high steel chimney stack to be erected at a Power Station for C.A. Energia Electrica de Venezuela. Some of the sections of this self-supporting stack assembled at Hulton Lane for proving before shipment are seen in this photograph. Overall height, 150 ft; diameter, 10 ft 6 in.; lower 70 ft length widening to 17 ft diameter at base. Weight 52 tons.



SPEED YOUR PROGRAMME.
Build in Steel
Now readily available

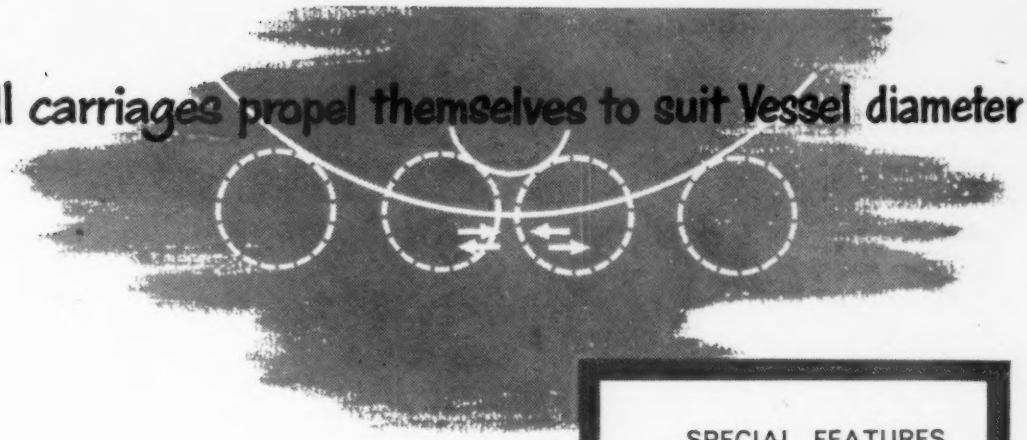
Steelwork by

BOOTH

for Bridges, Factories, Power Stations, Garages, Stores, Schools, Steel Fireproof Doors and Rolling Shutters, Steel and Glass Partitions.

JOHN BOOTH & SONS (BOLTON) LTD.,
Hulton Steelworks, Bolton. Telephone: Bolton 1195. London office: 26, Victoria Street, Westminster S.W.1 Tel. ABBey 7162

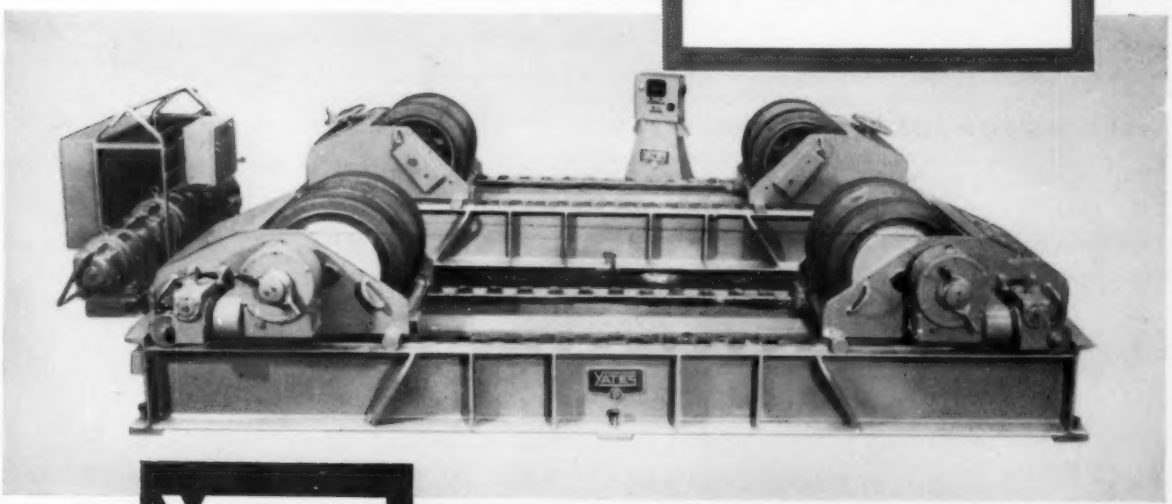
Roll carriages propel themselves to suit Vessel diameter



This new Heavy Duty Rotator incorporates the *exclusive* feature whereby the Roll Carriages propel themselves along the main frame to accommodate different diameter vessels. The carriages when positioned fall into positive locations and the need for carriage fixing bolts is eliminated.

SPECIAL FEATURES

- ★ Self Propelled Carriages, no manual adjustment.
- ★ Anti-Creep mechanism incorporated to prevent any *endwise* movement of vessel during rotation.
- ★ Internal gear Drive, giving exceptional vessel projection clearance.
- ★ Patented overload Shipping clutches fitted.
- ★ Control from Portable Pedestal and operates pendant switch.



THE YATES PATENTED

SELF PROPELLED CARRIAGE | **heavy duty rotators**

For further details write

YATES PLANT LIMITED *A member of Baker Perkins Group*

Whidborne Street, London, W.C.1.

BP/Y7

SCHOOL OF WELDING TECHNOLOGY

THREE NEW COURSES

PRACTICAL ULTRASONIC INSPECTION

4–15 JANUARY 1960

A special two-week training course, for operators, in the techniques of ultrasonic inspection.

WELDING OF ATOMIC ENERGY PLANT

8–12 FEBRUARY 1960

A one-week course for engineers, designers, and metallurgists to provide the latest information about the problems met with in this field.

WELDING FOR JUNIOR MANAGEMENT

23–25 FEBRUARY 1960

A three-day course for those holding junior positions in management to explain the factors involved in the proper application of welding.

FULL DETAILS OF THESE AND OTHER COURSES TO BE HELD BETWEEN NOVEMBER 1959 AND MARCH 1960 ARE GIVEN IN THE NEW PROSPECTUS

obtainable from

THE SECRETARY
THE INSTITUTE OF WELDING
54 PRINCES GATE
LONDON, S.W.7

Facts about NU-SWIFT

Nu-Swift Ltd., founded in 1933, is to-day the world's leading designer and manufacturer of portable fire extinguishers.

Nu-Swift extinguishers are installed in every ship of the Royal Navy, and in the ships of 17 other fighting navies.

They are in 3 Royal Yachts, including H.M. Yacht 'Britannia'.

In more than 70 countries, Nu-Swift extinguishers are installed and used for the protection of industrial, commercial, agricultural, transport and residential risks.

The annual output of Nu-Swift Ltd. now exceeds 250,000 units.

The number of employees in Britain has grown to 375, and the Nu-Swift Model Factory at Elland, Yorkshire, has had to be extended again and again.

The paid up capital of the Company is £210,000.

Reasons for success of NU-SWIFT easy-to-handle, certain-to-operate Extinguishers

The impressive record of Nu-Swift Ltd. is largely due to:

a) A bold decision to break with a tradition of manufacturing chemical extinguishers of doubtful efficiency and cumbersome operation which, until the advent of Nu-Swift, virtually held the field.

b) Purposive research and development, resulting in the design and manufacture of safe, efficient and reliable equipment of greater fire fighting power in relation to its size and weight.

c) Intensive mechanisation and the use of modern industrial techniques which have resulted in greatly improved products at low man-hour cost.

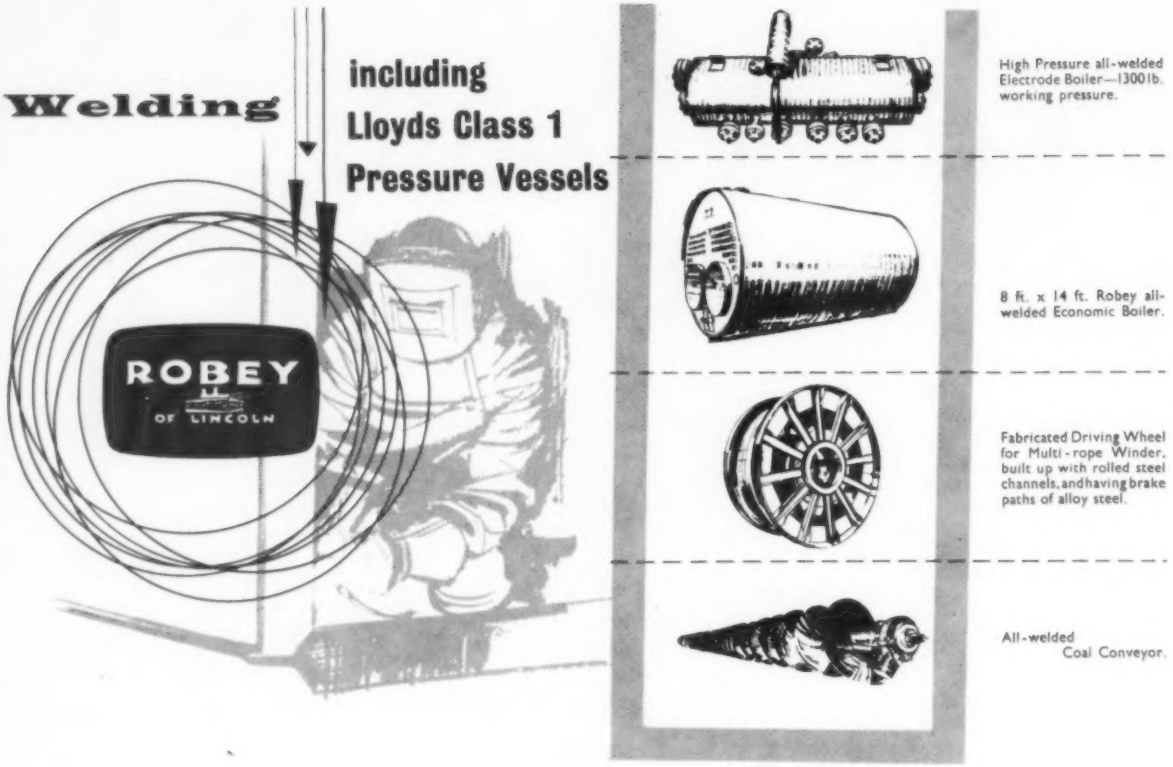
Safety, efficiency and reliability are vital factors in the design and manufacture of fire extinguishers. To these qualities, Nu-Swift has added simplicity of operation, standardisation to eliminate confusion, ease of maintenance, durability, and the facility for the rapid recharging of certain types.

Nu-Swift extinguishers are the best in the world, produced by a Company whose declared policy is that, in the fight against fire, when the amateur fire fighter has to battle alone, only the best is good enough.

Nu-Swift Fire Protection Centre, 25 Piccadilly, London, W.1

Wherever you are, in Britain or abroad, you will be wise to find out how Nu-Swift can protect you better.

NU-SWIFT LTD. · ELLAND · YORKSHIRE · ENGLAND


Welding
including
Lloyds Class 1
Pressure Vessels
ROBEY
OF LINCOLN
High Pressure all-welded Electrode Boiler—1300lb. working pressure.
8 ft. x 14 ft. Robey all-welded Economic Boiler.
Fabricated Driving Wheel for Multi-rope Winder, built up with rolled steel channels, and having brake paths of alloy steel.
All-welded Coal Conveyor.

ROBEY & CO. LIMITED P.O. BOX 23. LINCOLN · London Office: 11, Princes Street, Hanover Square, W.1.

ADVERTISERS' INDEX

Anglo-Swedish Electric Welding Co. Ltd. —
Booth, John, & Sons Ltd. 28
Braithwaite & Co. (Engineers) Ltd. —
British Industrial Gases Ltd. Inside front cover
British Insulated Callender's Cables, Ltd. 20
British Oxygen Gases Ltd. Outside back cover, 13
British Thomson-Houston Co. Ltd. —
Butterfield, W. P., Ltd. 12
Campbell, Malcolm (Plastics) Ltd. —
Carborundum Co. Ltd., The 3
Cooper & Turner Ltd. —
Courtburn Positioners Ltd. —
Distillers Co. Ltd., The 14
Dorman Long (Steel) Ltd. —
Electrothermal Engineering Ltd. —
English Electric Co. Ltd., The 16
Eutectic Welding Alloys Co. Ltd. 28
Flexello Castors & Wheels Ltd. —
General Electric Co. Ltd., The —
Gevaert Ltd. —
Hancock & Co. (Engineers) Ltd. —
Harvey, G. A., & Co. (London) Ltd. —
Head Wrightson Teesdale Ltd. 10
Hirst Electronic Ltd. 19
Ilford, Ltd. —
Imperial Chemical Industries Ltd. —
Invicta Electrodes, Ltd. 26
Jenkins, Robert, & Co. Ltd. 17
Johnson, Matthey & Co. Ltd. 2
Johnson, Richard, & Nephew, Ltd. 18
Kodak Ltd. —
Lincoln Electric Co. Ltd. 4
Marconi Instruments Ltd. 15
Marshall, Thomas, & Son, Ltd. 19
Marston Excelsior Ltd. —
Meritus (Barnet) Ltd. —
Mersey Cable Works Ltd. —
Metal and Pipeline Endurance Ltd. 5
Metropolitan-Vickers Electrical Co. Ltd. 6, 7
Milne, C. S., & Co. Ltd. —
Morris, B. O., Ltd. 22
Morrison, A. C. (Engineers) Ltd. —
Murex Welding Processes, Ltd. 25
Newton Victor Ltd. —
Norton Grinding Wheel Co. Ltd. 24
Nu-Swift Ltd. 31
Philips Electrical, Ltd. Inside back cover
Phillips, W. A., Anderson & Co. Ltd. —
Quasi-Arc Ltd. 8, 9
Robey & Co. Ltd. 32
Rockweld, Ltd. 1
Saturn Industrial Gases Ltd. 11
Siemens-Schuckert (Great Britain) Ltd. —
Smith, Hugh, & Co. (Possil) Ltd. —
Spencer Wire Co. Ltd., The 12
Stainless Steel Profile Cutters Ltd. —
Suffolk Iron Foundry Ltd. —
Welding Industries Ltd. 18
Welding Supplies Ltd. —
Wiggin, Henry, & Co. Ltd. 27
Yates Plant Ltd. 29

Published by The Institute of Welding, 54 Princes Gate, London, S.W.7
Made and Printed by Percy Lund, Humphries & Co. Ltd., London and Bradford

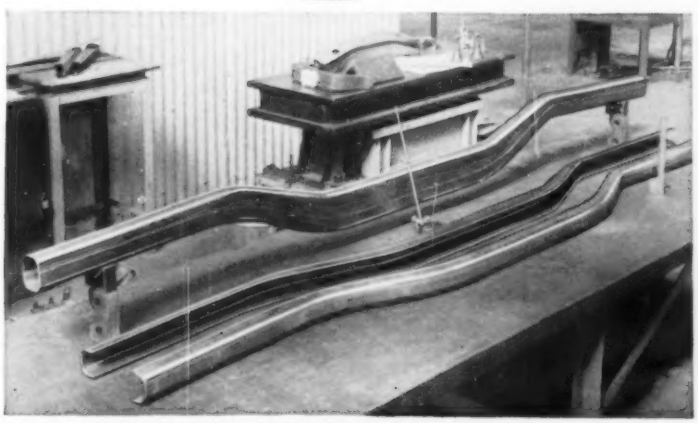
Solve your production problems with

PHILIPS

bare wire CO_2 welding machine

Philips AUTOMATIC CO_2 *bare wire* welding process is now available for immediate delivery in Britain. With this machine you can speed up mass production of welded parts, for example main chassis members, bottled gas cylinders, car wheels. And you can get welds protected from nitrogen and hydrogen by an atmosphere of CO_2 — which costs only a fraction of the price of argon. The absence of coating reduces the absorption of hydrogen, too.

- Welds very wide range of steel grades.
- Needs no stocks of expensive powders.
- Cuts labour costs by welding faster, requiring little attention in repeat operations.
- Welds are homogeneous with deep and even penetration.
- Arc is self-regulating . . .
- Nitrogen and hydrogen content low — no nitrogen porosity.



Component parts and finished vehicle chassis side member welded by Philips CO_2 process. *(Photo by courtesy of John Thompson Motor Pressings Ltd.)*

Philips Automatic CO_2 welding machine

provides automatic wire and CO_2 feeds. Travelling carriage moves along rails at speed set by operator. Water-cooled nozzle independent of main water supplies. Single control lever engages wire feed, switches on carriage motor and arc.

For further information about Philips CO_2 welding, and about Philips Automatic welding machine (a product of N.V. Philips, Eindhoven) write to:

PHILIPS ELECTRICAL LTD

INDUSTRIAL EQUIPMENT DIVISION

Century House, Shaftesbury Avenue, London WC2. GERrard 7777

(P10311)

Inside back cover

Always ask for "ALDA" rods and fluxes

BRITISH OXYGEN SUPPLY ALDA

—the famous range of rods and fluxes. And a complete range of welding accessories— from goggles and gloves to friction lighters and wire brushes.

ALWAYS ASK FOR ALDA.

Write for fully illustrated literature.

BRITISH OXYGEN

British Oxygen Gases Ltd., Industrial Division, Spencer House, 27 St James's Place, London, S.W.1.

Outside back cover